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Market Assessment of Photovoltaic Power Systems for Agricultural Applications in Colombia

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William Steigelmann
DHR, Incorporated

and

Sergio Neyeloff
ARD, Incorporated

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Prepared for
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Lewis Research Center
Under Contract DEN 3-180

for
U.S. DEPARTMENT OF ENERGY
Conservation and Renewable Energy
Division of Photovoltaic Energy Systems

NOTICE

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William Steigelmann
DHR, Incorporated
Washington, D.C.

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Burlington, Vermont

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ABBREVIATIONS AND ACRONYMS

ASOCANA	Sugar Cane Growers Association
ASOHUEVO	Egg Producers Association
ASOPOLLO	Broiler Producers Association
CENICAFE	Centro de Investigación del Café [Coffee Research Center]
CENICANA	Centro de Investigación de la Caña [Sugar Cane Research Center]
CIAT	Centro de Investigación de Agricultura Tropical [Tropical Agriculture Research Center]
COLPUERTOS	Colombian Port Authority
CORELCA	Corporación Electrica de la Costa Atlantica [Electric Corporation for the Atlantic Coast]
CVC	Corporación del Valle del Cauca [Corporation for the Cauca Valley]
DAINCO	Departamento Administrativo de Intendencias y Comisarias [Administrative Department for Districts and Commissariats]
DNP	Departamento Nacional de Planeación [National Planning Department]
DRI	Desarrollo Rural Integrado [Integrated Rural Development]
EEEB	Empresa de Energia Electrica de Bogotá [Electrical Energy Enterprise of Bogotá]
FEDEARROZ	Rice Growers Federation
FEDERCAFE	Coffee Growers Federation
FEDELLANOS	Cattlemen's Federation of the Llanos
FFNER	Fondo Financiero Nacional para Electrificación Rural [National Financial Fund for Rural Electrification]
HIMAT	Instituto Colombiano de Hidrologia, Meteorologia, y Adecuación de Tierras de Suelos [Colombian Institute for Hydrology, Meteorology, and Soil Improvement]
ICA	Instituto Colombiano Agropecuario [Colombian Institute for Agriculture]

ABBREVIATIONS AND ACRONYMS

ICEL	Instituto Colombiano de Energia Electrica [Colombian Institute for Electric Energy]
INCOMEX	Instituto Colombiano de Comercio Exterior [Colombian Institute of Foreign Commerce]
ISA	Interconexion Electrica, Sociedad Anonima [Electrical Interconnection, Incorporated]
kVA	kilovolt-ampere
kWh	kilowatt-hour
kWp	kilowatt peak
PERCAS	Programa de Electrificacion Rural de la Costa Atlantica y San Andres [Rural Electrification Program for the Atlantic Cost and San Andres]
PIN	Plan de Integracion Nacional [National Integration Plan]
PNER	Plan Nacional de Electrificacion Rural [National Plan for Rural Electrification]
PRODESARROLLO	Coffe Growers Federation Development Program
Wp	watt peak

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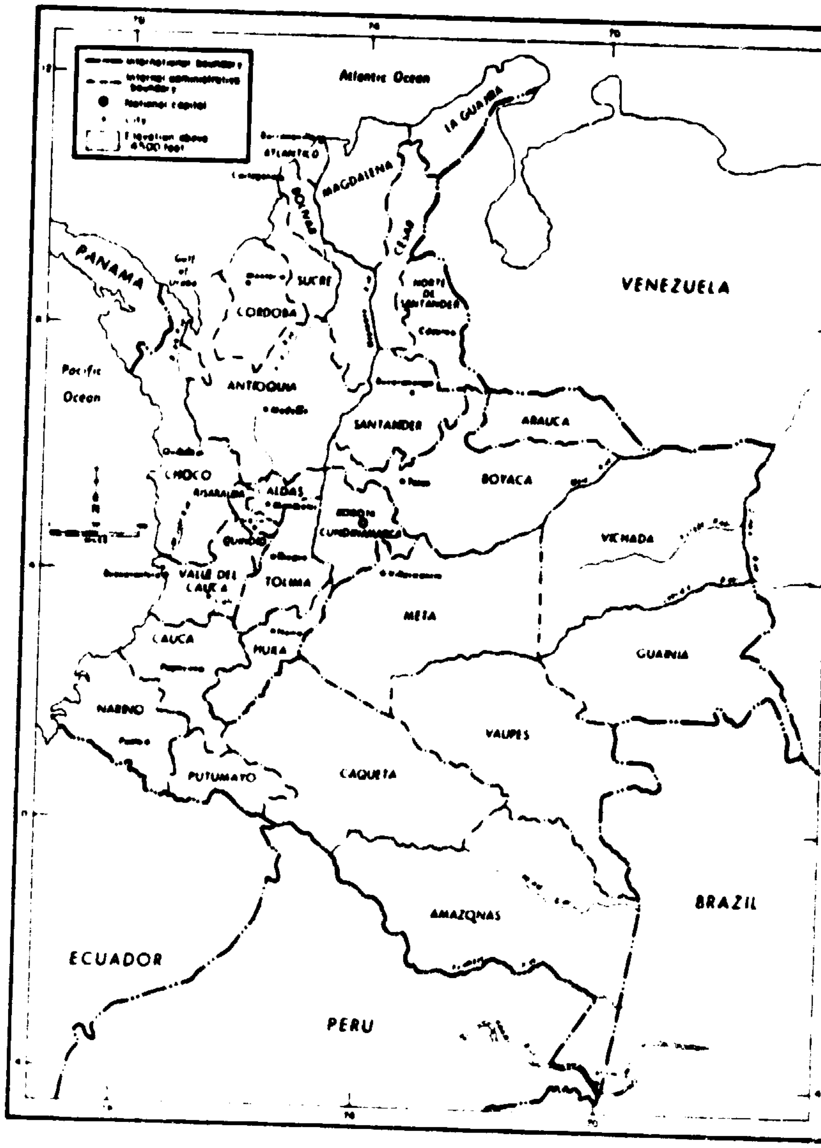

MAP OF COLOMBIA

Market Assessment of Photovoltaic Power Systems for Agricultural Applications in Colombia

Executive Summary

Objectives

The Photovoltaic Stand-Alone Applications Project Office of the NASA/Lewis Research Center, Cleveland, Ohio is sponsoring a study to assess the potential market for remote photovoltaic (PV) power systems in worldwide agricultural applications. This Colombia study is the last in a series of five country market assessments, following studies in the Philippines, Nigeria, Mexico and Morocco. The subject of these studies, namely agriculture, was broadly defined to include livestock and crop production and rural services. The primary purpose of the study is to help the American PV industry identify the applications and countries with a high PV sales potential so that it may develop appropriate marketing strategies. The following information essential to a marketing strategy for Colombia was gathered:

- Available financing sources and their respective terms and conditions of lending.
- Government and private development programs in the area of energy for agriculture.
- Government and private socio-economic development programs in rural areas.
- Development programs in rural communication.
- Present overall energy situation and future energy generation and usage projections.
- Cropping practices and power requirements for a variety of agricultural operations.
- Social and economic characteristics of the agricultural sector.
- Private and government programs and policies that may have a direct bearing on PV system availability and desirability.
- Import policies and regulations and channels for distribution of PV equipment.
- Estimates of potential market size for PV applications in various sectors.
- Initial and operating costs of power systems that would compete with PV.
- Appropriate methods of doing business in Colombia.

The types of applications considered are those requiring less than 15Kw of power and operating in a stand-alone configuration without back-up power.

Study Approach

A research team consisting of one DHR and one ARD specialist, accompanied by a NASA representative, arrived in Bogota, Colombia on June 28, 1981, for a 3-4 week study of agricultural, rural and other activities which might use U.S. PV powered equipment in Colombia. Close to a hundred contacts were made with embassy officials, Colombian government officials, local businessmen, importer/exporters, local manufacturers, education and research institution personnel, utility company personnel, alternate energy groups, agricultural experts and farmers in key agricultural regions. Site visits were made to obtain power requirements and energy use profile data for several agricultural applications. The data acquired during the visit was used to characterize the environment in which PV systems would be marketed and used. Data on applications was used to identify cost-competitive end-uses. The potential market size for these end-uses were estimated based on cost-competitiveness, availability of finance, government policies, and other factors.

Status of PV in Colombian Energy Development Plan

Colombia's development strategy emphasizes expansion of domestic energy output in the 1980's to stimulate further economic growth. Investments in the energy sector under the current four year plan (1979-1982) focus on hydropower development, exploration and development of petroleum resources and the development of natural gas and coal, principally for export.

Due to the fact that Colombia is well-endowed with conventional power sources, especially coal and hydro, alternate energy development is not a high priority of the Colombian government. Conventional energy activities are motivated more by rural development objectives than a desire to replace existing energy sources.

TELECOM, the Colombian Telecommunications Authority, has begun a large project to use photovoltaics for rural telephone transmissions. In 1980, TELECOM awarded a contract totalling $3 million to a British engineering firm to supply 1550 PV-powered telephone units and to Italtel for 450 PV-powered telephone systems. ARCO Solar provided the PV panels to the British firm. A second stage of the program will provide telephone service to an additional 2200 rural communities.

The current Colombian energy situation favors the use of renewable energy sources, including photovoltaics, especially in rural areas. Gasoline and diesel prices have risen steadily due to the Turbay Administration's policy of gradually introducing world market prices to discourage demand. The cost of transportation to remote regions can raise the cost of diesel and other fuels to in excess of US $4.00 per gallon because it must often be transported by boats or small planes. Furthermore, the costs of extending the electric grid to remote locations are often prohibitive given Colombia's mountainous terrain and widely dispersed rural population.

The lack of electricity and other energy sources in some rural areas has led to widespread deforestation. Furthermore, certain remote regions, especially the Guajira peninsula and the Eastern Plains, receive especially favorable solar insolation levels.

Implications of Colombian Agricultural Development Plans for PV Systems

Colombian agricultural development plans have led to the establishment of the Integrated Rural Development Program to directly provide technical assistance to 157,000 farm families and to provide infrastructure and satisfy basic needs in rural areas. The three major program areas are production, social welfare and infrastructure. 1982 expenditures are planned to be $104, $30 and $44 million respectively. The production program consists of programs for credit, technological development, marketing organizational training and natural resources conservation. The social welfare program includes programs for rural aqueducts, education and health. The infrastructure program has local road building and rural electrification components.

Presently 87% of the rural sector, that is 1,113,000 rural families, are without electrical service. The Colombian government and electrical utilities have considerable plans for expansion of the areas served with electricity. Good progress is anticipated in the near term, but it is also estimated that as many as 40% of the rural families will not have access to electrical service in any foreseeable future. The reason is that it would be simply too expensive to extend the grid to such remote areas since the population is too poor and too sparse. Electrification programs for the 1980's will aim at providing power to all those users who can afford it and who are within 5 kilometers of the power grid. A program for installing micro-generating diesel and hydroelectric plants will also be put into effect. These plants will have capacities ranging from 100 to 200 KW. About 35 are planned and they will serve about 3,000 families each in regions isolated from the power grid.

The implications of these agricultural and rural development programs are: (a) improved ability to finance PV systems and (b) the very large number of rural Colombians remaining dependent on stand-alone power sources.

Availability of Financing Mechanisms and Funds

Colombian laws have made considerable provisions for credit to be made available to the agricultural sector. Even with such provisions, it is estimated that only half of Colombian farmers have any access to credit. The major sources of financing for Colombian farmers are the Fondo Financiero Agropecuario (Agriculture and Livestock Finance Fund) of the Bank of the Republic and the Caja Agraria. The Fondo Financiero Agropecuario supplies supervised credit for growing specific crops. The Caja Agraria directs 30% of its resources to medium-sized farmers. 70% goes to small farmers in the form of loans averaging US $840 in size. Such loans are usually for seed and fertilizer.

With Caja funds going to such basic needs, the possibility of Caja financing of PV was not enthusiastically considered by the Caja representative contacted. Other government agricultural credit bank representatives, in particular those of the Banco Ganadero, were more enthusiastic for cost-competitive applications. However, a reluctance to finance or use new technologies was noted.

The availability of financing for photovoltaic systems to Colombian farmers other than the very wealthy landowners is contingent upon PV equipment qualifying under existing law for the same financing that currently applies to diesel generators. A Banco Ganadero representative indicated that they would qualify. About $24 million was lent for the purchase of agricultural machinery under the Fifth Law (Ley V) in 1980. The terms of these loans were a 4-6 year life of the loan, a 21.0% interest rate, and an 18.5% rediscount rate.

Assuming PV can be demonstrated to be cost-competitive with diesel for rural areas, then perhaps 10% of the agricultural machinery funds, or roughly 2.4 million dollars, could be made available for PV purchases.

Potential PV Applications in Colombian Agriculture

During the visit to Colombia, seven technically and economically feasible agricultural applications were identified. These are: Coffee de-pulping/general domestic uses; cattle water stations; rural domestic uses; rural water supply and small irrigation; rural telephones; rural health posts; and vaccine refrigeration.

1) Coffee De-pulping and Domestic Uses

An estimated 10% of the smaller coffee farms lack electrical energy to power their de-pulping equipment. These farms typically use a 2 HP gasoline engine. It is estimated that as many as 8,000 such systems are in operation, but the average use is only about 120 hours/year. While these small de-pulping machines use 2 or 3 HP engines, the actual requirements are in the order of 0.75 to 1 HP. Larger engines are used just because they are available. In fact, a vertical drum type de-pulping machine has recently been developed and is now being marketed. It uses a 0.5 HP electric motor. The actual power requirement is listed as 0.36 HP.

Systems installed for de-pulping coffee berries would also be used for general domestic electric needs and could be used to power fans to enhance coffee drying.

2) Cattle Water Stations

The cattle industry in the Oriental Plains (Llanos) may present a market for fairly small PV power systems. Two areas of need are cattle watering during dry seasons and domestic electrical needs for households. A lack of water during some periods of the year is the major problem for the industry. Gasoline and diesel powered pump sizes range from a few horsepower to 15-20 HP on the larger ranches. Because of the great costs of flying in repair parts and fuel, gasoline and diesel powered pumping stations are very seldom used for cattle and a reliable substitute would be more than welcome. Consultation with cattle ranchers indicates that ideally a watering station ought to be provided for each group of 300-400 animals. The water table may be as deep as 10 meters (30 ft.). The average is about 5 meters (15 ft.). Pumping energy required, based on a daily pumping volume of 24 cubic meters and a 10 meter total dynamic head, is about 1.5 kwh/day (assuming a 50% pumping system efficiency).

Beside the possibility of using PV systems for pumping water into reservoirs, Llanos spokesmen saw a potential for small systems to be used for domestic needs.

3) Rural Domestic Uses

Time and time again the need for basic electrical service to rural families was pointed out by contacts in Colombia.

Despite intensive electrification programs, a large number of rural inhabitants will not have electric services in the late 1980s. Herein lies some potential for PV equipment: Three types of possible users exist:

- Wealthy ranchers and land owners who presently have small diesel or gasoline powered generator sets. Indications are that people would buy PV systems at a premium price due to convenience (e.g., no need to transport fuel).
- Those who require electricity but simply are not close enough to the power grid for this to be economically possible. These would be the 16,000 landowners who own land in the range of 200-1,000 hectares. A portion of this group might buy PV systems if they were competitive with gasoline powered generators in the 1-3 KW range.
- Small individual families needing basic lighting and radio power. Unfortunately, few if any rural families have access to $2500 or $3000 to acquire a small PV system (income less than US$200 per year). The only possibility in this area would be for those families involved in the production of established, marketable produce such as coffee, which may count on the help of programs such as Prodesarroll.

4) Rural Water Supplies and Small Irrigation

According to some of the contacts made in Colombia there would be a market for PV powered pump sets to satisfy domestic water, and small irrigation needs for rural families. About 5,000 pump sets are being sold yearly in Colombia, the vast majority being small 3-5 HP gasoline sets. To a great extent these are used as standby equipment due to the unreliability of centrally generated power and for applications where the portability of this equipment is important. In many cases, gasoline powered pump sets are purchased solely for convenience rather than need. Based on conversations with pump distributors, agricultural experts and producers, one could deduce that these sets (average 3 HP) are used one-half to one hour per day, year around, and pump water into reservoirs, or large tanks.

5) Rural Telephones

Phase II of the Colombian Telecommunication Authority program, solicitations for which will be released late in 1982, calls for 2,200 PV powered pay phones to be installed. The complete program seeks to provide telephones to every locality with a population exceeding 200 inhabitants.

6) Rural Health Posts

The health problems in Colombia are in rural areas due to the inability of medical personnel to reach and provide vaccinations to people in rural, isolated regions.

Health posts, attended by a nurse or nurse's aid and perhaps a doctor on occasion, number 1,500 in Colombia. In isolated areas posts may have engine generator sets in the range of 1.5-3.0 KW and are used only 3½ hours a day. Refrigerators are kerosene powered.

Power systems for health posts would be sized in the range of 1.5-3.0 KWp with storage capacity for 3 days.

The market for these power systems would probably be limited to new installations or to those where generators are being replaced. Funds for the purchase of such equipment would have to come from the Colombian government or a national or international health organization. There is a drawback to the use of PV systems on some rural health posts in that power is needed in a fairly erratic schedule, as and emergencies occur, and under those conditions there is a tendency to favor gasoline powered equipment.

7) Vaccine Refrigeration

There are about 3,000 Colombian rural health promoters; each covers an area of about 3 square miles. They travel on horseback or bicycles, obtaining their vaccines from health posts or centers. Vaccines are kept refrigerated in thermos bottles. Small refrigerator-freezers for vaccines of the cold-chain type (polio, measles, etc.) may be a potential application for PV systems. The thermos-type containers presently carried can maintain proper temperatures for up to two days.

There are areas of the country that are simply out of reach for medical teams since they cannot keep medication properly refrigerated for extended periods of time. Life expectancy in those areas may be as little as 35 years. The social and economic benefits of having PV powered refrigeration for this purpose are hard to estimate. However, a small PV powered refrigerator could be the key to improving the health of people in these remote regions since feasible alternatives to PV powered refrigerators do not exist.

Cost Analyses and Market Size Estimation

Technical feasibility was judged in terms of the suitability of the load characteristics, use profile and operating environment to PV use. Applications that require low power levels, minimal battery capacity, stable year-round energy demand and an environment detrimental to conventional power sources were considered most suitable for PV application. Economic feasibility was based on comparing the life-cycle costs of a PV system to that of a conventional gasoline or diesel power system. Since PV system costs are declining and energy costs from conventional systems are increasing, at some point in time the costs will be equal. An application is considered economically feasible for this study if cost-competitiveness is reached prior to 1986.

After 1986, PV cost reduction expectations will make them economically competitive with grid electricity, thus opening up a vast new market for PV. The cost and technical parameters used to evaluate potential applications are shown in Table 1.

The market estimation procedure used is based on the premise that a market will start developing when PV systems are cost-competitive, on a life-cycle basis, when compared to the least cost, practical alternative. At this point, the market share for PV will be close to zero as the conventional systems

have the advantages of existing supply and repair infrastructure, tradition, and less initial capital investment. Once the cost equality point is passed, their rate of penetration will be determined by market-related factors. Another assumption made is that PV systems will have greatest acceptance by those currently using conventionally powered equipment. The bound on the market is estimated to be the peak power required for the total number of cost-competitive, practical applications. The upper bound is then adjusted by a subjectively determined market penetration rate to obtain the 1981-86 market size. The penetration rate is determined by factors such as: level of awareness, first year of cost-competitiveness, financing availability and institutional barriers/incentives.

Table 1

COST AND TECHNICAL PARAMETERS USED IN COST-COMPETITIVE ANALYSIS

Discount Rate (%)	12
Analysis Life (years)	20
Fuel Cost--Gasoline ($/gallon) Diesel	0.88-2.25 0.70-1.75
Real Fuel Cost Escalation %	5
Life of Conventional Power Systems (years)	5-10
Battery Life (years)	5
Battery Cost ($/AH)	1
Solar Insolation (langleys/day)	

J	F	M	A	M	J	J	A	S	O	N	D	Average
450	445	420	375	370	350	380	410	430	360	390	390	398+33(std. dev.)

	1980	1982	1984	1986
PV system cost $/Wp without batteries (includes a 10% CIF surcharge over JPL cost projection)	18.89	8.86	6.56	4.26

NOTE: All costs are measured in 1980 dollars and discount and fuel escalation rates are measured in real terms after factoring out inflation.

Market Assessment

As determined by the team, the market for PV power systems in Colombia for the period 1981-86 lies in the range of 1200 to 2500KWp. Due to current status of government and private sector activities and attitudes the most probable effective market size will becloser to the lower figure. Table 2 gives the summary of the market.

TABLE 2

MARKET SIZE ESTIMATE FOR PV POWER SYSTEMS IN COLOMBIA, IN THE 1981-86 PERIOD

APPLICATION	ARRAY SIZE KWp	FIRST YEAR OF COST COMPETITIVENESS	MARKET SIZE RANGE KWp
Coffee Sector	0.48 - 0.68	1982-84	308-1060
Livestock	0.34	1982	102-170
Rural Electricity Uses	1.15	1982-84	460-805
Rural Water Supply Small Irrigation	0.5	1983-84	150-250
Rural Telephones	0.072	1982	158-168
Rural Health Posts	1.75	1983	73-95
Vaccine Refrigeration	0.1	1982	3-5
			1254-2553

Business Environment for Marketing PV Systems

American PV manufacturers attempting to develop the Colombian market will face important advantages and disadvantages. The princpal advantages are:

1) Large percentage of rural population wihout electricity
2) High cost of grid extension
3) Maintenance and fuel supply problems associated with internal combustion engine generators
4) Availability of long-term financing if PV can be proved to be cost-effective

Against these factors the following disadvantage must be weighed:

1) Unfamiliarity with PV, especially in the rural sector
2) Government preference for mini-hydro systems for electrification of remote areas
3) Large hydroelectric potential
4) Reluctance of agricultural sector to use new technologies

5) Foreign PV competition

6) Lack of incentives for use of or investment in photovoltaics.

The team encountered many Colombians who confused photovoltaic systems with solar water heating systems, which are now the subject of a tax incentive proposal. Awareness of PV is generally low, with an estimated 20-25% of contacts having any substantial knowledge of PV systems.

Among government officials involved in energy planning, understanding of PV technology and possible applications is widespread. Furthermore, there is a general recognition that stand-alone systems are the only answer to electrification needs in remote areas, and an aversion to further use of diesel generators due to maintenance problems and high fuel transport costs. However, several DNP and ICEL officials expressed reluctance towards PV due to its high first cost and a preference for mini-hydro systems for remote electrification.

Agriculture sector officials were generally aware of photovoltaics but not of possible agricultural applications. ICA, FEDEGAN and Banco Ganadero officials were enthusiastic about the possibility of using PV for livestock watering in remote regions such as the Eastern Plains. These individuals claimed that livestock owners represents a large potential private market for PV because they have the capital to invest in PV equipment and need electricity for both water pumping and domestic uses. Based on the best information available to the team, eight firms, three of which are Americans, are currently marketing photovoltaics in Colombia. The non-American firms include the German firms AEG-Telefunken and Messerschmidts, the Dutch firm Phlllips and the Japanese firms SHARP and SANYO. Current photovoltaics marketing activity appears to be centered on the Colombian government, and has increased recently due to TELECOM's purchase of PV equipment for rural telephone communications. TELECOM has requested Inter-American Development Bank financing for the second phase of the project.

Other Colombian government entities which have expressed interest in photovoltaics include:

- Empresas Departamentales de Antioquia--PV powered telephone centrals and UHF television receivers

- INRAVISION--installation of 6-7KW television receivers in 10 mountainous locations

- AEROCIVIL--installation of 5KW air navigation signals in 6 mountainous areas

- Dirección Marítima y Portuaria--17 PV-powered buoys for maritime signalling

- Ministry of Health--"SEM"--Malaria Eradication Service--PV-powered vaccine refrigerators

- ECOPETROL--Cathodic protection

In addition, potential private markets include:

- FEDEGAN--PV-powered water pumps for cattle watering
- Private Clubs--6-7KW radio repeaters
- Agricultural Cooperatives--radio repeaters

Several contacts expressed the belief that PV sales in Colombia would increase if a foreign company established an assembly operation in the country. Most balance of system components, such as batteries, glass, wiring, etc. are produced in Colombia so that a joint-venture arrangement seems feasible. However, many Colombian firms are rich in engineering expertise and skilled workers, yet capital poor. Colombia's economy is characterized by relatively high inflation, high interest rates, and a steadily depreciating exchange rate. These factors lead Colombian investors to prefer quick returns on their investment of at least 30-35%. PV may not interest many Colombian private investors because of the long payback period (about 10 years) usually associated with it. All these factors indicate that U.S. firms would probably have to provide most of the initial capital for such a venture.

In order to maximize the photovoltaic market potential in Colombia, U.S. firms should:

1) Offer complete systems (e.g., PV-powered water pumps, refrigerators, etc.)

2) Perform as much as possible of the production and assembly of PV systems in Colombia or another Andean Pact country to avoid higher tariffs

3) Consider forming a corporation under Colombian law with majority Colombian participation to take advantage of ANCOM's liberal trade policy and open up markets in other member nations.

Conclusions

Colombia presents a promising market for photovoltaic equipment. Over twenty applications of PV systems were investigated during the field visits Several applications, requiring less than 5KW of power, present a significant market potential in the 1981-86 timeframe. Market size ranged from 1200-2500 KWp in 1981-86 timeframe. Factors positively influencing the PV market are summarized below:

- Lack of electrical services. Less than 60% of potential users are now being served by the electrical utility companies--there are an estimated 1.6 million families without electricity.

- Electrical generation plans behind schedule. While there exists extensive plans for the exploitation of hydroelectric power, these plans are not expected to meet demand for many years. Blackouts, planned or otherwise, occur about every day. Alternatives are being sought.

- Llanos Orientales Development. The vast Llanos Orientales Territory lacks electrical power and estimates are that this area will continue to be unelectrified. There is a great potential for agricultural and small industry development in this area and this would require power.

- Cost of Fuel in remote regions. While fuel is relatively inexpensive in developed areas, it may cost 2 to 3 times as much in remote regions due to transportation costs. PV systems would be competitive in the early 1980's with presently used gasoline or diesel generators in remote areas.

- Balance of system availability. Colombia is fairly industrialized; there are at least 10 large companies making automobile batteries and many more manufacturing electrical equipment. Deep discharge batteries are not presently manufactured, but given the market, the industry may tool-up easily. Expertise in electricity and electronics is abundant; installation and maintenance of PV powered systems would not be problem.

- Wealthy Land Owners. While the per capita income in Colombia is low on the average, there are many very wealthy land owners who could afford PV systems to replace presently used generator sets or other equipment for cattle watering, domestic electrical users, small irrigation etc.

On the negative side one also finds important factors which regard to PV applications. They are summarized below:

- Relatively inexpensive energy in most locations. In the highly developed Andean region prices for gasoline and diesel are below a dollar a gallon, and prices for electricity range from 3 to 7 cents/kwh.

- Reliance on Hydropower. Colombia has a great potential (about 20 times the existing capacity) for hydroelectric power generation. Justifiably many contacts felt that PV systems may have little application if present development plans are carried through.

- Lack of Familiarity with PV equipment. The majority of contacts made confused PV cells with solar thermal panels. Farmers and others involved in agriculture had no knowledge of such systems. Research and development in the area is non-existent for all practical purposes.

- Lack of Financing. The longest term financing available is 6 years for agricultural equipment; and interest rates are high. While a life cycle cost analysis may show cost-competitiveness for PV equipment, it may be out of reach for many users due to high initial cost.

MARKET ASSESSMENT OF PHOTOVOLTAIC POWER SYSTEMS FOR AGRICULTURAL APPLICATIONS IN COLOMBIA

1.0 INTRODUCTION

1.1 Study Objectives

The Photovoltaic Stand-Alone Applications Project Office of NASA/Lewis Research Center, Cleveland, Ohio, has issued a contract to conduct an assessment of the market for stand-alone photovoltaic (PV) power systems in worldwide agriculture. The primary purpose of this study was to provide a data base and and an analysis of the market for PV in worldwide agriculture. The study was to help industry identify the applications and countries with a high PV sales potential so that it may develop appropriate market strategies.

The present report is the fifth in a series of field studies, following studies in the Philippines, Nigeria, Mexico and Morocco. The subject of these studies, namely the agricultural sector, was broadly defined to include livestock, crop production and rural services. Additionally opportunities for PV in other rural sector applications were investigated, although not in the same degree of detail.

The motivation for the study is that PV costs have been coming down dramatically due to improved cell technology and mass-production methods, and further cost reductions are projected which will make PV price-competitive in applications where at present it is not. The objective of the study was to find cost-competitive PV applications and their market potential. For the economic comparison, the study was based on the PV cost projections of the JPL[1/], which was the most complete and up-to-date projection of PV costs available. The JPL projected PV costs to come down as follows:

PROJECTED COST OF PV POWER, INSTALLED IN THE U.S., IN JULY 1980 DOLLARS PER PEAK WATT (Wp)

	Cost of Solar Cells	System Cost w/o Battery Storage Capacity	Battery Storage Cost	System Cost With Battery Storage Capacity
July 1980, stand-alone system	10.60	17.17	3.68	20.85
1982 cost, stand-alone system	2.80	8.05	3.68	11.73
1986 cost, stand-alone system	0.70	3.87	2.68	6.55
1986 cost, residential system	0.70	1.60	-	-

For more detail see Tables 1.1 through 1.4 at the end of this Chapter.

1/ "1980 Photovoltaic Systems Development Program Summary Documents." Jet Propulsion Laboratory, Pasedena.

The above table shows that an enormous cost reduction is projected for the solar cells, while the cost of balance-of-system (BOS) elements--in particular the storage batteries--will descend a lot more slowly and thus form an increasing share of the total cost. The important point at the moment, however, is that in 1986 electricity produced by a residential PV system is projected to be cost-competitive with conventional grid electricity as a daytime fuel saver. At that point large markets will be opened for PV arrays in grid-connected domestic and industrial systems. Whenever this happens, the market for PV in remote stand-alone applications will be dwarfed in comparison. Thus the main interest in stand-alone applications from the PV manufacturers' point of view, lies in their market potential up to 1986. (Note that if the year of PV cost-competitiveness for residential systems arrives later than projected, PV cost-competitiveness in remote stand-alone systems will be similarly delayed). Furthermore, prediction of the market beyond 1986 on the basis of production technologies which are still at the laboratory stage or not yet in existence can only be a speculation. Note moreover that by 1986 the cell cost is projected to be only \$0.70/Wp out of a total stand-alone system cost of \$3.87-6.55/Wp and no large further cost reductions are projected for the balance of system elements, so that even a very large reduction of PV cell costs after 1986 will not make PV cost-competitive in most stand-alone applications in which it is not cost competitive by 1986. Based on these considerations, the present study has concentrated on investigation of the market for PV in agricultural and rural applications over the period 1981-1986.

1.2 Topics and Scope of the Study

During the course of this study information essential to the development of a market assessment was gathered. This information includes the following:

- Available financing sources and their respective terms and conditions of lending.
- Government and private development programs in the areas of energy for agriculture.
- Government and private socio-economic development programs in rural areas.
- Development programs in rural communication.
- Present overall energy situation and future energy generation and usage projections.
- Cropping practices and power requirements for a variety of agricultural operations.

- Social and economic characteristics of various sectors.
- Private and government programs and policies that may have a direct bearing on PV system availability and desirability.
- Import policies and regulations and channels for distribution of PV equipment.
- Estimates of potential market size for PV applications in various sectors.
- Initial and operating costs of power systems that would compete with PV.
- Appropriate methods of doing business in Columbia.

1.3 Conduct of Study

A research team consisting of one DHR and one ASD specialist, accompanied by a NASA representative, arrived in Bogota, Colombia on June 28, 1981, for a 3-4 week study of agricultural, rural and other activities which might use PV powered equipment in Colombia. The initial (1 week) part of the study concentrated on efforts to assess the overall energy situation in the country and to interview personnel from several agencies to establish a specific course of study covering the more promising potential users. In this phase of the study, personnel from the U.S. Embassy, DNP, DRI, ICEL, HIMAT, TELECOM FEDECAFE AND ICA were conculted. These early contacts provided an extensive list of future contacts and sources of information which would be helpful in conducting the rest of the study.

Close to a hundred contacts were made through the course of the visit and included government officials, local businessmen, importer/exporters, local manufacturers, education and research institution personnel, utility company personnel, alternative energy groups, agricultural experts and farmers.

The team also travelled to several key agricultural areas and research institutes to obtain information. A list of contacts made is presented in Appendix A.

A considerable amount of literature was obtained and consulted in the preparation of this report; a bibliography is in Appendix E. The type of data collected included the following:

- Aggregate statistics including: Level of agricultural production; type of production; distribution of production by size of operation; solar insolation; production trends.

- End-use system configuration description and characterization of current agriculture practices in terms of: operations; machinery used/duration of use; availability of resources (labor, parts, energy, etc.); PV impacts; economics; financing; and diesel/gasoline/electricity use.
- Balance of systems availability and barriers to the implementation of PV systems that are related to: costs and availability of balance of system parts or equipment; skills of workforce.
- Government attitudes and policies including: the level of awareness or interest in PV - especially units of less than 15KW for agriculture purposes, and policies conducive to, or hindering, PV marketing and use.
- Labor availability and cost and skills of workforce, nationally and regionally.
- Government energy policies, both planned and existing relative to: rural electrification; prices/supply; renewable energies; consumption; type of energy used; PV systems.
- Government agricultural policies, both existing and planned, with regard to: crop production; introduction of new techniques and equipment; role of PV systems in agriculture; incentives (financial and other); land reform/land use; employment generation; import of agricultural systems; storage; research work; marketing.
- Marketing channels and identification of potential barriers/incentives in the marketing of PV systems, including the present structure of markets; buying patterns; service/installation; profits; availability of equipment, and costs of competing systems.
- Financing mechanisms and availability of credit for PV use in agriculture.
- Business environment, incentives and barriers that U.S. companies face when planning to conduct PV business or organize joint ventures.

1.4 Data Analysis and Market Assessment

The information gathered during the visit was used to characterize the environment in which PV systems would be marketed and used.

For economic comparisons of PV power systems to alternatives, the data requirements include power requirements; usage profiles; the extent of current and future use in Colombian agriculture; competing systems cost; financial and economic parameters; solar insolation data; and PV system costs. These economic and usage data were used in DHR's "PV Market Assessment" computer model. This model computes life-cycle costs, and the year in which the PV system first becomes cost-competitive with its nearest competitor. Figure 1.1 is an overview of the DHR methodology.

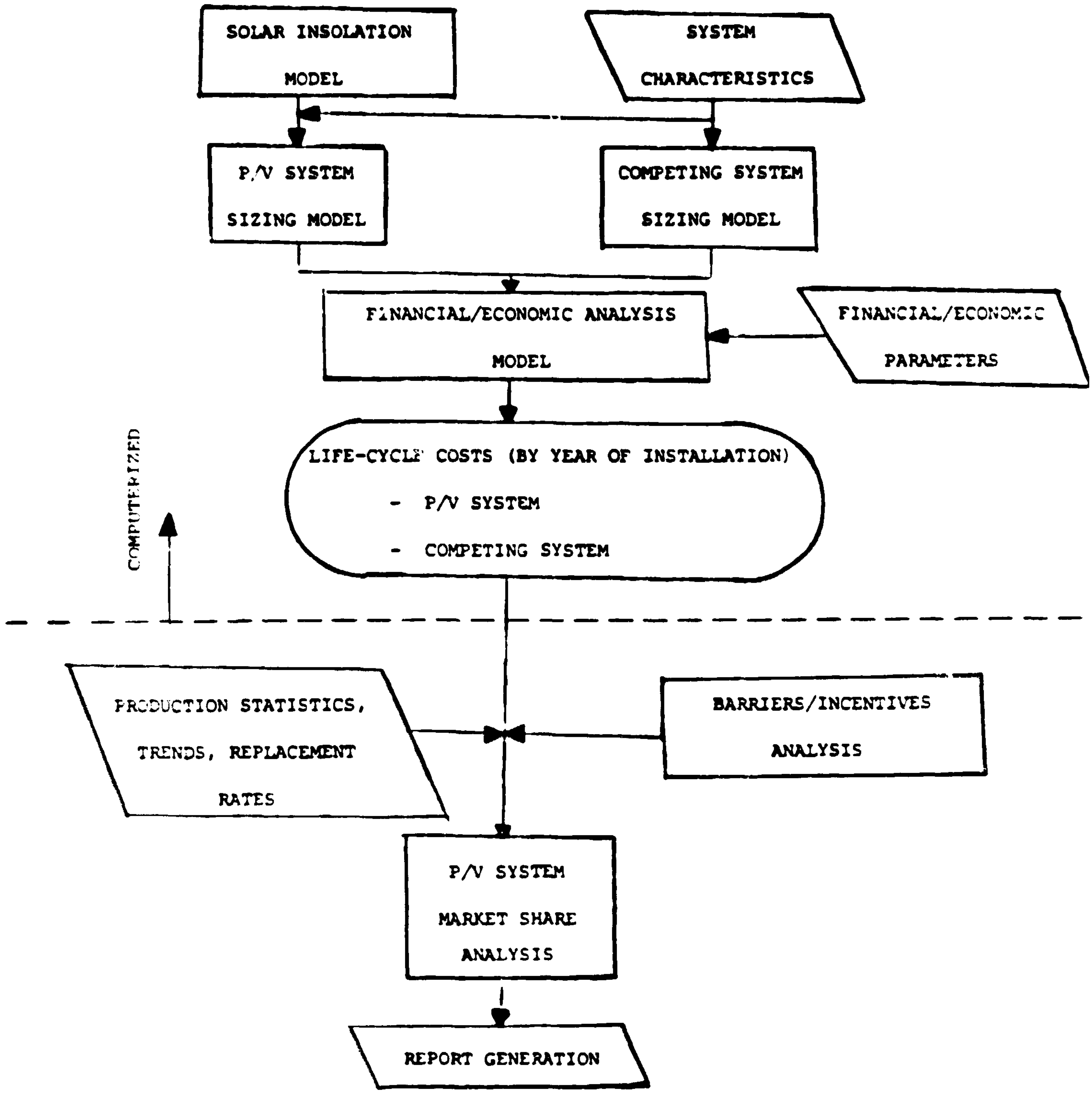

FIGURE 1.1 DHR P/V MARKET SIZE ESTIMATION PROCEDURE

It should be noted that market size estimation procedures used in this analysis assumes that if PV is to obtain a significant market share, it must be cost-competitive with the least-cost, practical alternative. There are, of course, special cases where other advantages of PV systems far outweigh cost concerns. Examples of such applications are rural telephones and vaccine refrigeration. When appropriate, such applications will be noted.

The qualitative analysis, the cost-competitiveness data, and the information on extent of use, are combined and used to obtain an estimation of the probable market for PV systems through the year 1986. Due to uncertainties present in such analyses a range of figures is given as to the size of the PV market.

1.5 Report Organization

The report is organized so that background demographic, social and financial aspects are covered first and then an analysis is presented of the specific PV application possibilities.

Chapter 2 gives an overview of the demographic, agricultural and energy situation in Colombia. Chapter 3 presents the Colombian economic and energy development plans. Chapter 4 addresses the financial situation relevant to PV marketing. Chapter 5 describes the business aspects of marketing PV system in Colombia. Chapter 6 presents an analysis of those applications for PV systems that were found to offer a significant market in the 1981-86 timeframe. Chapter 7 describes applications for which the use of PV power systems is not considered feasible or significant in that timeframe. Chapter 8 discusses the major conclusions regarding the PV market in Colombia.

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TABLE 1.1: 1980 COST OF A 20kWp REMOTE STAND-ALONE PV SYSTEM
(IN JULY 1980 DOLLARS)

	SYSTEM COST ELEMENT	INITIAL PRICE $/W, (1980$): MANUFACTURER	INITIAL PRICE: MARKETING & DISTRIBUTION	INITIAL PRICE: INSTALLATION	INITIAL PRICE: SUBTOTAL	ENERGY PRICE ELEMENT $/W, (1980$): INITIAL INSTALLED SYSTEM PRICE	ENERGY PRICE ELEMENT: LIFE CYCLE OPERATION & MAINTENANCE	LEVELIZED ENERGY PRICE, ¢/kWh (1980 $): 2350 kWh/kWp	1770 kWh/kWp	1400 kWh/kWp
ARRAY	• Collector	10.60	INCL	0.81	11.41	13.60	0.13	102.4	145.2	183.6
	• Structures & Foundations	0.60	0.12	0.40	1.12					
	• Site & Preparation	–	–	0.56	0.56					
	• Field Wiring	–	–	0.44	0.44					
	• Lightning Protection	–	–	0.07	0.07					
POWER CONDITIONING	• Power Conditioner	0.43	INCL	0.05	0.54	0.86	0.13	7.7	10.2	12.9
	• Electrical Switchgear & Wiring	0.11	0.06	0.05	0.22					
	• Control System	–	–	0.10	0.10					
STORAGE	• Battery	2.60	0.52	0.08	3.20	3.68	2.80	48.0	63.7	80.6
	• Charger	0.10	0.03	0.04	0.17					
	• Battery Building	–	–	0.31	0.31					
INDIRECTS	• System & Project Management, Engineering				2.71	2.71		21.6	28.7	36.3
	• Spare Parts				0					
	• Interest During Construction									
TOTAL	INSTALLED SYSTEM	14.50	0.73	2.91		20.85	3.06	186.7	247.8	313.4
TOTAL w/o BATTERY STORAGE		11.60	0.18	2.49		17.17	0.26	–	–	–

Assumptions:

- PV [illegible] Efficiency [illegible]
- Marketing & Distribution: Collector [illegible], [illegible] & Equipment [illegible]
- [illegible] Design and [illegible] Management, [illegible]
- Lifetime: System [illegible] years, [illegible] 20 years.
- Operation & Maintenance: $[illegible]/kWp/yr.
- Utilization Factor (?): 0.[illegible]
- Fixed Charge Rate: 0.12
- Discount Rate After Taxes (k) [illegible]
- Battery: $[illegible]/kWh Initial [illegible] Price; [illegible] year life, [illegible] Storage ([illegible] kWh/kWp)
- Inflation Rate [illegible]
- Capital Recovery Factor [illegible]

Source: JPL, "1980 Photovoltaic Systems Development Program Summary Document" (Draft)

TABLE 2.1

PROJECTION OF PRODUCTION, CONSUMPTION, IMPORTATION AND EXPLORATION OF MAJOR FUELS 1980-1989 (Millions of Barrels)

	Gasoline			Diesel		Jet Fuel		Kerosene		Fuel Oil		
Year	Prod.	Con.	Imp.	Prod.	Con.	Prod.	Con.	Prod.	Con.	Prod.	Con.	Exp.
1980	21.6	26.6	5.0	8.8	8.8	3.6	3.6	3.0	3.0	12.5	8.3	4.5
1981	24.0	27.7	3.7	9.3	9.3	3.9	3.9	3.1	3.1	15.1	8.9	6.3
1982	23.3	28.8	5.5	9.7	9.7	4.2	4.2	3.2	3.2	15.1	11.0	4.1
1983	30.0	30.0	—	10.1	10.1	4.6	4.6	3.2	3.2	19.9	11.5	8.4
1984	31.2	31.2	—	10.6	10.6	5.0	5.0	3.3	3.3	21.3	11.6	9.6
1985	32.5	32.5	—	11.1	11.1	5.4	5.4	3.3	3.3	22.6	12.4	10.2
1986	33.8	33.8	—	11.5	11.5	5.8	5.8	3.4	3.4	24.1	12.7	11.4
1987	35.2	35.2	—	12.0	12.0	6.3	6.3	3.5	3.5	26.3	13.1	13.2
1988	33.3	36.6	3.3	12.5	12.5	6.8	6.8	3.6	3.6	26.6	13.5	13.1
1989	31.9	38.1	6.2	13.0	13.0	7.4	7.4	3.6	3.6	27.0	13.9	13.1
Total	296.8	320.5	23.7	108.6	108.6	53.0	53.0	33.2	33.2	210.4	116.9	92.8

SOURCE: Plan de Integración Nacional 1979-1982, Tomo II. Departamento Nacional de Planeacíon, Bogota, Colombia, 1980.

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TABLE 1.2: 1982 COST PROJECTIONS OF A 20 KWp REMOTE STAND-ALONE PV SYSTEM
(IN [illegible] DOLLARS)

	System Price Element	Initial Price $/Wp: Manufacturing	Initial Price $/Wp: Marketing & Distribution	Initial Price $/Wp: Installation	Initial Price $/Wp: Subtotal	Energy Price Elements: Initial Installed System Price	Energy Price Elements: Annual Operation & Maintenance	Levelized Energy Price ¢/kWh: 2300 kWh/kWp	Levelized Energy Price ¢/kWh: 1770 kWh/kWp	Levelized Energy Price ¢/kWh: 1400 kWh/kWp
ARRAY	• [illegible]	2.[illegible]	0.84	0.40	4.04	5.84	0.13	47.5	63.1	79.7
	• [illegible]	0.5[illegible]	0.1[illegible]	0.30	0.90					
	• [illegible]	-	-	0.50	0.50					
	• [illegible]	-	-	0.35	0.35					
	• [illegible]	-	-	0.50	0.05					
POWER [illegible]	• [illegible]	0.22	0.11	0.05	0.38	0.70	0.13	6.4	8.6	10.7
	• [illegible]	0.11	0.06	0.05	0.22					
	• [illegible]	-	-	0.10	0.10					
STORAGE	• BATTERY	2.60	0.52	0.08	3.20	3.68	2.80	48.0	63.7	80.6
	• CHARGER	0.10	0.03	0.04	0.17					
	• BATTERY [illegible]	-	-	0.31	0.31					
INDIRECTS	• [illegible]	X	X	X	1.51	1.51	X	12.0	15.9	20.1
	• [illegible]	X	X	X	0					
	• [illegible]	X	X	X	-					
TOTAL	[illegible]	7.33	1.66	2.23	X	11.73	3.06	113.9	151.3	191.1
TOTAL	W/O BATTERY [illegible]	3.63	1.11	1.80	X	8.05	0.26	-	-	-

Assumptions

- [illegible]
- [illegible]
- [illegible]
- [illegible]
- Operation & Maintenance: [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- Inflation Rate: [illegible]
- Capital Recovery Factor: [illegible]

[illegible]

TABLE 1.3: 1986 COST PROJECTIONS OF A 100 kWp REMOTE STAND-ALONE PV SYSTEM (IN JULY 1980 DOLLARS)

	SYSTEM PRICE ELEMENT	INITIAL PRICE ($/Wp) (1980$): FOR MANUFACTURER	MARKETING & DISTRIBUTION	INSTALLATION	SUBTOTAL	ENERGY PRICE ELEMENTS ($/Wp) (1980$): INITIAL INSTALLED SYSTEM PRICE	LIFE CYCLE OPERATION & MAINTENANCE	LEVELIZED ENERGY PRICE, ¢/kWh (1980$): 2350 kWh/kWp	1770 kWh/kWp	1400 kWh/kWp
ARRAY	• Collector	0.70	0.21	0.20	1.11	2.49	0.13	19.0	25.2	31.9
	• Structures & Foundation	0.40	0.08	0.20	0.68					
	• Site & Preparation	-	-	0.40	0.40					
	• Field Wiring	-	-	0.25	0.25					
	• [illegible]	-	-	0.05	0.05					
POWER CONDITIONING	• Power Conditioner	0.11	0.06	0.05	0.22	0.54	0.13	4.7	6.2	7.9
	• Electrical Switchgear & Wiring	0.11	0.06	0.05	0.22					
	• Controls & Wiring	-	-	0.10	0.10					
STORAGE	• Battery	1.83	0.37	0.08	2.28	2.68	2.04	32.0	42.5	53.7
	• Charger	0.10	0.03	0.04	0.17					
	• Battery Building	-	-	0.23	0.23					
INDIRECTS	• Design & Project Management Fee				0.84	0.84		6.1	8.1	10.2
	• Sales Fee				0					
	• Interest During Construction									
TOTAL, COMPLETE SYSTEM		3.25	0.81	1.65		6.55	2.30	61.8	82.0	105.7
TOTAL, w/o BATTERY STORAGE		1.32	0.41	1.30		3.87	0.26	-	-	-

Assumptions

- 10% Collector Area Efficiency
- Marketing & Distribution: Collector 30%, Structure 20%, Power Conditioning & Electrical [illegible]%, Storage & Equipment 20%
- Fees, Design and Project Management [illegible]%, Sales [illegible]%
- Lifetimes: System 20 years, Batteries 20 yrs
- Operation & Maintenance: $16/kWp/year
- Utilization Factor (U): 0.70
- Fixed Charge Rate: 0.12
- Discount Rate: After Taxes (b) 8%
- Battery Storage: 3 days ([illegible] kWh/kWp), $120/kWh Initial Price, 10 years
- Inflation Rate (g): [illegible]
- Capital Recovery Factor: 0.10

Source: JPL, "1980 Photovoltaic Systems Development Program Summary Document" (Draft)

2.0 DEMOGRAPHIC OVERVIEW

With an estimated population of 26.8 million in 1980, Colombia is the third most populous nation in Latin America after Brazil and Mexico. Its growth rate in the 1970's declined to 2.7% per year due to an ambitious family planning program. Per capita gross national product was US$1010 in 1979. Approximately one-third of the population is rural, a proportion which has been declining since the 1960's due to large scale urban migration. Nevertheless, agriculture continues to play a major role in Colombia's economy, contributing 23% of gross domestic product in 1980.

Colombia's land area of 440,000 square miles makes it the fifth largest country in Latin America. The country is dominated by three ranges of the Andes mountains which cross the country on a northeasterly axis. The population is concentrated in the plateau and basins of the three ranges and the valleys between them. Northeast of the Andes lie the Llanos Orientales (Eastern Plains); to the South-east lies the Amazon jungle.

About 45% of Colombia's territory is forested. The mountainous terrain of the highlands and swamps and jungle at lower elevations limit the utilization of land. Only 3% of the national territory is farmland, of which 13% is in permanent and seasonal crops, 53% is in pasture, 23% is fallow, and the remainder is forested or unused. The fertile flatlands tend to be devoted to large-scale commercial farming while cattle raising and small farm plots characterize the mountain slopes.

Average farm size in Colombia was estimated at 26 hectares by the last agricultural census, taken in 1970. However, average farm size is a poor indication of land tenure in Colombia because of extremes in actual farm size. Seventy-three percent of the farms in 1970 were less than 25 acres in size and occupied only 7 percent of total farmland. Most of these small farms were concentrated in the departments of Boyacá, Cundianmarca and Nariño. At the other extreme, the census showed that 10 percent of the farms were ranches with poor quality soils suited only for livestock raising.

Coffee is the most important crop in Colombia, contributing about 10 percent to GDP, and 60-65% to export earnings annually. Because of the geographical range of coffee-growing areas in the country, two harvests per year are reaped. Coffee grows throughout Colombia, but the principal coffee growing regions are located in the departments of Antioquia, Quindio and Caldas. Sugarcane, the second most important crop,is grown principally in the Cauca Valley and along the Atlantic Coast, and is highly efficient. Cotton is mostly grown on the Atlantic

Coast and cotton production has been stimulated by the government in order to provide the raw material for Colombia's large textile industry. Rice, a basic staple of the Colombia diet, is cultivated primarily in Tolima Department, where yields per acre rank among the highest in the world, and two crops per year are grown. Other important crops include plaintains, bananas, cassava, corn, tobacco, flowers and potatoes. Further information about major export and domestic crops can be found in Appendix C.

2.1 Energy Situation Overview

Despite abundant underdeveloped energy resources, Colombia faces sever energy shortages. Once a petroleum exporter, Colombia's oil production declined in the early 1970's and by 1975 the country became a net importer. Electrical demand has strained system capacity resulting in both planned outages and the frequent unscheduled blackouts throughout most of the country in 1980. Contributing causes include light rainfall which reduced hydroelectric output, delays in completion of several key generating facilities and higher than anticipated energy demand. Government officials predict that the outages will continue until 1982 when generating plants currently under construction should come on line.

Colombia's development strategy emphasizes expansion of domestic energy output in the 1980's to stimulate further economic growth. Investments in the energy sector under the current four year plan (1979-1982) focus on hydropower development, exploration and development of petroleum resources and the development of natural gas and coal, principally for export.

Colombia's known petroleum reserves total 1055 million barrels. After nearly a decade of decline, petroleum production rose slightly in 1980, and is expected to rise marginally in 1981 and 1982 due to increased exploitation of existing fields. New discoveries in the Magdalena River Valley and the Northern Llanos could make Colombia self-sufficient again by 1985. At present, some 17% of Colombia's net petroleum needs are met by imports. Projections of supply and demand for petroleum based fuels made by ECOPETROL, the Colombian Petroleum Corporation, are presented in Table 2.1.

Present tested natural gas reserves in Colombia total about 4.7 billion cubic feet. Some 79% of the gas reserves are located in the off-shore and on-shore areas of the Guajira peninsula. Recent exploratory drilling has revealed the possible existence of considerable gas reserves along the Caribbean off-shore region, particularly in the Atlantic coastal region. Future plans calls for the extension of gas supply lines to the inland cities of Medellin and Cali, the export of liquified petroleum gas and the production of ammonia urea and/or methanol as a substitute for motor gasoline. Projections of

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consumption and surplus production of gas in the Atlantic Coast region from 1980 through 2000 are described below in Table 2.2.

TABLE 2.2

PROJECTIONS OF CONSUMPTION AND SURPLUS PRODUCTION OF NATURAL GAS IN THE ATLANTIC COAST REGION 1980-2000 (Millions of cu.ft/day)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1995	2000
Potential Gas Production	264	350	450	450	450	450	450	450	450	450	450	450	450
Consumption of Gas	120	130	131[1]	136	146	147	147	147	147	147	147	147	147
Power Generation	25	26	27	28	29	30	31	32	33	34	35	45	45
Current Production	65	68	72	76	80	85	90	96	102	108	110	130	130
Other Industries	210	224	230	240	255	262	268	275	282	289	292	322	322
Other Users	54	126	220	210	195	188	182	175	168	161	158	128	128

SOURCE: Plan de Integración Nacional 1979-1982, Tomo II. Departamento Nacional de Planeación, Bogotá, Colombia, 1980.

Coal is Colombia's largest fossil fuel resource, with reserves estimated at 11.0 billion metric tons, the largest in Latin America. Because little coal exploration has been conducted in Colombia, it is likely that reserve estimates will continue to rise with increased exploration. Coal production totalled about 5.5 million metric tons in 1980. About 53% of Colombia's known reserves are located within 120 miles of Bogotá. An additional 32% lie near the Caribbean coast, in the El Cerrejon deposit, part of which will be developed for export in a joint venture agreement between CARBOCOL, the government coal enterprise and INTERCOR, an EXXON affiliate. Exports from El Cerrejon are expected to reach 16 million tons in 1990, making Colombia a major coal exporter and providing significant export earnings through the year 2007.

Hydroelectric power is Colombia's principal source of electricity, accounting for 69% of a total installed capacity of 4246 MW in 1980. This capacity is distributed among several regional and municipal utilities, as seen in Table 2.3. Colombia is relying heavily on the development of its hydro resources to keep pace with electrical demand. In 1980 the failure of capacity to keep up with demand led to widespread blackouts. Hydroelectric potential was estimated at 93,085 MW in a recent study of the electric energy sector, as described in Table 2.4.

TABLE 2.3

INSTALLED CAPACITY OF THE ELECTRIC ENERGY SECTOR

	TOTAL CAPACITY		HYDROELECTRIC CAPACITY		THERMOELECTRIC CAPACITY	
Entity[1]	MW	%	MW	%	MW	%
ISA	500	12.4	500	17.1	0	0.0
EEEB	684	16.9	548	18.8	136	12.2
EPM	999	24.8	999	34.2	0	0.0
CVC	584	14.5	534	18.3	50	4.5
ICEL	682	16.9	339	11.6	343	30.7
Sub-Total Central System[2]	3449	85.5	2920	100.0	529	47.4
CORELCA	587	14.5	0	0.0	587	52.6
TOTAL[3]	4036	100.0	2920	100.0	1116	100.0

1. ISA-Interconexión Eléctrica S.A., EEEB-Empresa de Energía Eléctrica de Bogotá, EPM-Empresas Publicas de Medellín, CVC-Corporacion Autónoma del Cauca, ICEL-Instituto Colombiano de Energía Eléctrica, CORELCA-Corporación Eléctrica de la Costa Atlantica.
2. The Central grid will be interconnected with the CORELCA grid in 1982 by a 500 KV line.
3. Not including are some independent generators and localities supplied by small generators not interconnected with existent subsystems.

SOURCE: Plan de Intergración Nacional 1979-1982, Tomo II. Departamento Nacional de Planeación, Bogotá, Colombia, 1980.

TABLE 2.4

HYDROELECTRIC POTENTIAL OF COLOMBIAN WATERSHEDS

Watershed	MW	Percent
Magdalena and Cauca Rivers	35,470	38.0
Orinoco and Catatumo Rivers	27,330	29.4
Pacific Ocean Tributaries	12,120	13.0
Atrato and Sinu Rivers	4,450	4.8
Amazon River	12,020	13.0
Sierra Nevada	630	0.7
Others	1,065	1.1
TOTAL	93,085	100.0

SOURCE: "Colombia's Energy Outlook for the 1980's," Colombia Today, Vol. 14, No. 12, 1979.

In the 1979-1983 period some US$12.5 billion will be spent on electric power development. This includes investments in power generation and distribution by the major regional and municipal utility companies and national projects undertaken by the Electrical Interconnection Corporation (ISA). By 1982, the CORELCA grid, which is currently isolated, will be connected with the central grid. Also planned is the construction of two large water reservoirs to assure sufficient water pressure for hydro projects. Planning for the electric sector is based on an 80-20 ratio of hydro to thermal plants.

Colombia has no plans for the construction of nuclear power plants. However, the newly created government enterprise COLURANIO has entered into three association contracts for the exploration and development of uranium. The director of the government Nuclear Affairs Institute estimates that Colombia's uranium oxide reserves may be as much as 40,000 tons, but little exploration has taken place so far. The Ministry of Mines and Energy does not preclude the possibility of using nuclear energy towards the end of the century, when Colombian technology and know-how will be more advanced.

2.2 Alternative Energy Activities

Due to the fact that Colombia is well-endowed with conventional power sources, especially coal and hydro, alternate energy development is not a

high priority of the Colombian government. Conventional energy activities are motivated more by rural development objectives than a desire to replace existing energy sources. Colombia's rugged topography and dispersed rural population make it extremely difficult and expensive to reach rural communities with transmission lines and fuels. The lack of electricity and other energy sources in some rural areas had led to widespread deforestation. Furthermore, certain remote regions, especially the Guajira peninsula and the Eastern Plains receive especially favorable solar radiation levels (See Appendix D).

The Colombian government is interested in using non-conventional sources to provide energy to rural communities at a lower cost than traditional resources. ICEL, the Colombian Electric Energy Institute, is the executing agency for a two million dollar pilot program for using solar, wind and biomass energy in rural areas. ICEL has also developed a plan for installing 35 minihydro generators with capacities ranging from 100 kw to 500 kw for a total capacity of about 6.8 MW. Furthermore, in 1979, ICEL, CHEC (Hydroelectric Generating Plants of Cauca) and ENEL, The Italian State Electrical Corporation, began a geothermal research project whose final stage is the installation of an experimental 10 MW pilot plant.

The pioneer in the development of alternate technologies for rural development in Colombia is the Centro Las Gaviotas, a private research organization founded in 1968. The 20,000 acre Las Gaviotas settlement is located in the Orinoco River Basin in the national territory of Vichada. Its main objective is to develop technologies and farming techniques appropriate to the tropical savannah environment of eastern Colombia. One such product is a double-effect windmill designed for water pumping at low wind speeds and depths up to 30 meters. The Las Gaviotas factory produces about 3000 windmills per year for use in Colombia and export to other developing nations. Other innovations include a 10 KW axial hydroelectric turbine driven by water from a small stream, a manual sugar cane press, a bicycle-powered cassava grinder and a minimal head turbo-pump.

Las Gaviotas technicians also designed and constructed the world's largest solar water heating installation for 62 apartment buildings in Medellin. Two thousand solar water heating units are currently being installed in a similar apartment complex in Bogota. Las Gaviotas mass produces a US$480 solar water heater for six-person households.

In 1978, the United Nations Development Program singled out Las Gaviotas as the developing world's leading center of appropriate technology research. UNDP provides one million dollars per year for Las Gaviotas operations. Significant funding has also come from the Colombian government, the Dutch government, and private organizations. The Director of Las Gaviotas, Dr. Paolo Lugari, believes that the center's industrial activities will earn enough money in the future to finance its research and development activities.

2.3 Photovoltaics Activities

Photovoltaics research in Colombia is centered at the Department of Physics of the Universidad Nacional in Bogota, and is at the level of laboratory scale experimentation. In addition, research into high frequency PV water pumping is taking place at the Universidad de los Andes in Bogota. No production of PV cells is currently taking place in Colombia. The Centro Las Gaviotas has received several proposals from American and Japanese manufacturers to set up PV demonstrations but has not made any decisions yet. Las Gaviotas technicians are especially interested in PV for water pumping applications in the Llanos region.

TELECOM, the Colombian Telecommunications Authority, has already begun a large project to use photovoltaics for rural telephone transmissions. In 1980, TELECOM awarded a contract to Lucas Energy Systems, Ltd., a British engineering firm, to supply 1550 PV-powered telephone units. A similar contract was granted to Italtel for 450 PV-powered telephone systems. In all, some 2000 rural communities will receive public telephone systems by 1982. The systems range in size between 30 and 120 watts. Total cost for the first stage of the Rural Telephone Program is about three million dollars and average cost per watt is US$25.

During the second stage of the Rural Telephone Program 1982-86, TELECOM will provide telephone service to an additional 2200 rural communities. The solicitations for this project will be released in mid-1982 and three months will be allowed for submittal of bids. Private as well as public telephone installations will be included.

Whereas the first stage installations were concentrated in the

populous Andean region, the second stage will include installations in the national territories of eastern and southern Colombia and the departments of the Pacific Coast and Magdalena River Basin. The Rural Telephone Program seeks to provide telephone service to all communities of over 200 people.

The second stage of the Rural Telephone Program is tied into the Colombian satellite program, SATCOL. Under this plan, 150 receiving stations will be sited in rural areas for telecommunications use in conjunction with a space satellite. It is highly likely that these 150 stations will use PV as their power source. However, the rural stations have third priority after the installation of receiving stations in 6 major cities and 15 minor cities. TELECOM officials stressed that the second stage of the Rural Telephone Program can be implemented without use of the satellite if need be.

2.4 Implications of the Energy Situation and Government Energy Plans for PV Systems

The current Colombian energy situation favors the use of renewable energy sources, including photovoltaics, especially in rural areas. Gasoline and diesel prices have risen steadily due to the current Administration's policy of gradually introducing world market prices to discourage demand. Currently, gasoline costs about 88 cents per gallon and diesel about 70 cents per gallon. However, as seen in Table 2.5, the cost of transportation to remote regions can raise the cost of diesel and other fuels to in excess of US$4.00 per gallon because it must often be transported by boats or small planes. Furthermore, the costs of extending the electric grid to remote locations are often prohibitive given Colombia's mountainous terrain and widely dispersed rural population (see Rural Electrification Plans, Section 3.2).

At this time, however, photovoltaics is not a priority in Colombian energy planning. This is partly due to the low level of awareness (see Section 5.1) and partly due to the perception that it is too expensive for a country at Colombia's stage of development. Some Colombian officials expressed the belief that if the energy needs of Colombia's rural population are to be met at all, it must be on a least cost basis.

TABLE 2.5

PRICES FOR DIESEL AND OIL IN VARIOUS REMOTE LOCALITIES IN THE INTENDENCIES AND COMISSARYSHIPS OF EASTERN COLOMBIA

Locality	Diesel Cost US$/Gallon	Motor Oil Cost US$/Gallon
Tame, Arauca	1.56	10.40
Yopal, Casanare	1.10	6.40
San Luis de Palenque, Casanare	1.30	8.00
Mocoa, Putumayo	.90	5.66
Puerto Asis, Putumayo	.92	6.40
Puerto Carreno, Vichada	1.70	7.80
La Primavera, Vichada	1.80	12.00
Puerto Inirida, Guainia	1.70	7.28
San Felipe, Guainia	4.36	9.40
Barrancominas, Guainia	1.80	7.28
Leticia, Amazonas	1.90	9.10
Mitu, Vaupes	4.20	9.24

NOTE: Prices based on exchange rate of 50 Colombian pesos per U.S. dollar. "Intendencias" or Intendencies and "Comisarias" or Comissaryships are political units which lack the autonomous administration of the departments.

SOURCE: Evaluación Plan Trienal, Inventário Plantas Eléctricas Diesel y Consumo de Combustible y Aceite. Departamento Administrativo de Intendencias y Comisarias-DAINCO-División de Infraestructura, Sección Energía, Bogotá, Mayo 22 de 1981.

3.0 COLOMBIAN DEVELOPMENT PLANS

3.1 Economic Outlook and Development Plans

Real economic growth in Colombia slowed to 4.5 percent in 1980, the lowest increase since 1975. This was largely the result of a restrictive monetary policy designed to stem inflation with tight credit and high interest rates. The policy succeeded in reducing inflation from 29.8% in 1979 to 26.5% in 1980. However, the unemployment rate increased from 1979's level of 8.9% to 9.3% in 1980. Under employment estimated at 15.4% of the total labor force in 1980, posed a problem particularly in rural areas.

Exports totalled US$3.751 billion and imports US$5.4 billion in 1980, resulting in a trade deficit of US$1.649 billion. In 1979 Colombia had registered a trade surplus of US$530 million. International reserves reached an estimated US$5.4 billion as of December 31, 1980, the highest ever. Coffee exports, illegal drug revenues and international loans are expected to keep international reserves high in 1981.

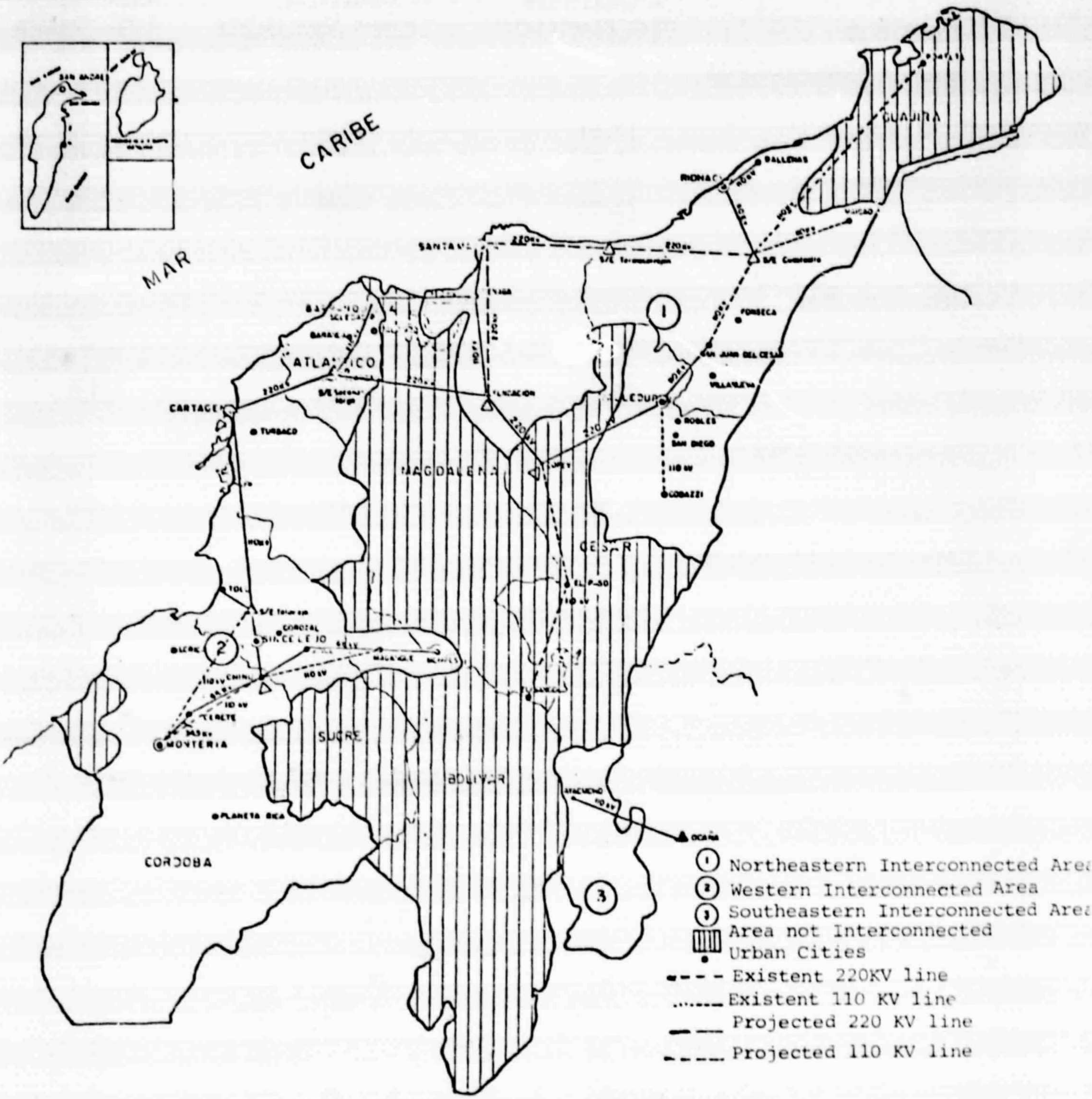
Crawling peg devaluation of the peso by the Colombian government during 1980 totalled 15.0%. Some Colombian exporting sector representatives insisted that an accelerated devaluation rate was necessary in order to maintain competitiveness in the face of domestic inflation.

Accelerated inflation is expected throughout most of 1981 due to increases in wage levels in the rural sector, higher gasoline prices, and a ten percent authorized increase in rents and leases. These inflationary pressures may be counteracted somewhat by decreased food prices as crop conditions improve. A slight relaxation of the Colombian government's tight monetary policy, especially for productive activities, should increase overall production by late 1981. Growth in gross domestic product for 1981 is expected to be about 5%.

Another inflationary factor cited by some analysts is the Integrated National Development Plan (PIN). Covering the period 1979-1982, the plan calls for major infrastructure investments, some of which are financed by foreign loans The PIN also emphasizes the development of the transportation, communications, energy, mining and social sectors through a variety of specific programs. Total public investment during the four year period is expected to reach US$6 billion.

FIGURE 3-1.

ELECTRIC NETWORK OF THE ATLANTIC COAST AND SAN ANDRES



SOURCE: Programa Regional de Electrificación Rural-Costa Atlantica y San Andres, CORELCA, Enero, 1981.

3.2 Rural Electrification Plans

A major part of the PIN is the National Rural Electrification Plan (PNER). The PNER covers fifteen departments under the jurisdiction of ICEL and the CVC (Corporation of the Valley of Cauca) as well as the four "intendencias" and four "comisarias" of eastern Colombia. Electric service will be provided to some 145,000 households currently without electricity between 1980 and 1983. The extent of the coverage of PNER by department is shown in Table 3.1. Average coverage is 13.5% of unelectrified rural residences per department. Of those covered approximately 30% are located in coffee-growing regions, 60% in agrarian zones and 10% in other zones (dispersed populations of less than 2500 inhabitants). The Federacion Nacional de Cafeteros, or National Coffeegrowers Federation, is actively involved in the electrification program in the coffee zones.

TABLE 3.1

DISTRIBUTION OF RURAL RESIDENCES COVERED BY PNER BY DEPARTMENTS

Department	Rural Residences without Electricity	Rural Residences Covered by PNER	Residences in Coffee Zone	Residences in Agrarian Zones
Antioquia	161,700	21,600	8,200	13,400
Boyacá	180,000	21,500	1,800	19,700
Caldas	27,900	3,700	3,000	700
Cauca	73,100	9,800	3,000	6,800
Cundinamarca	117,700	15,800	6,400	9,400
Chocó	33,700	4,500	–	4,500
Huila	36,700	4,900	2,600	2,300
Meta	20,000	2,700	350	2,350
Nariño	82,800	12,500	2,100	10,400
Norte de Santander	48,100	6,200	2,400	3,800
Quindio	4,900	700	–	700
Risaralda	16,000	2,100	1,500	600
Santander	92,600	12,400	3,200	9,200
Tolima	70,700	9,500	4,500	5,000
Valle	65,600	8,800	4,000	4,800
Resto del País	61,900	8,300	450	7,850
TOTAL	1,080,300	145,000	43,500	101,500 (*)

*Includes residences in other zones.

SOURCE: La Electrificación en Colombia, Informe 1979-1980. Ministerio de Minas y Energía, Instituto Colombiano de Energía Eléctrica.

The execution of the PNER necessitates the design and construction of 23,000 KM of high and low tension lines, the installation of 10,000 transformers and the construction of 145,000 domestic installations. Costs of electrification in several departments are presented in Table 3.2.

TABLE 3.2

COSTS OF ELECTRIFICATION BY DEPARTMENT

(November 1980 dollars)

Department	Cost Per Km of Primary Lines	Cost Per Km of Secondary Lines	Cost of Structure With Transformer	Cost of Domestic Installation
Antioquia	9,799 (1) 7,305 (2) 7,973 (3)	6,670 (4) 9,796 (5)	1,645 (6) 1,655 (7)	140
Boyacá	7,500	5,000	1,540	150
Cauca	5,940	6,720	1,[illegible]0	260
Cundinamarca and Meta	3,766 (8)	3,326 (8)		150
Chocó	15,494	18,359	982	736
Nariño	5,740	5,300	1,700	80
Norte de Santander	4,439	4,500	2,523	143
Santander	3,374	4,228	1,446	160
Tolima	3,000	3,000		160

NOTES: (1) Single concrete structure
(2) Single wood structure
(3) Single ingot structure
(4) Untreated wood
(5) Treated wood
(6) Wood and concrete mounted
(7) Rail structure
(8) Not including cost of transport of materials to work site

SOURCE: ICEL

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3.2 Rural Electrification Plans

A major part of the PIN is the National Rural Electrification Plan (PNER). The PNER covers fifteen departments under the jurisdiction of ICEL and the CVC (Corporation of the Valley of Cauca) as well as the four "intendencias" and four "comisarias" of eastern Colombia. Electric service will be provided to some 145,000 households currently without electricity between 1980 and 1983. The extent of the coverage of PNER by department is shown in Table 3.1. Average coverage is 13.5% of unelectrified rural residences per department. Of those covered approximately 30% are located in coffee-growing regions, 60% in agrarian zones and 10% in other zones (dispersed populations of less than 2500 inhabitants). The Federacion Nacional de Cafeteros, or National Coffeegrowers Federation, is actively involved in the electrification program in the coffee zones.

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Cauca	73,100	9,800	3,000	6,800
Cundinamarca	117,700	15,800	6,400	9,400
Chocó	33,700	4,500	–	4,500
Huila	36,700	4,900	2,600	2,300
Meta	20,000	2,700	350	2,350
Nariño	92,800	12,500	2,100	10,400
Norte de Santander	48,100	6,200	2,400	3,800
Quindio	4,900	700	–	700
Risaralda	16,000	2,100	1,500	600
Santander	92,500	12,400	3,200	9,200
Tolima	70,700	9,500	4,500	5,000
Valle	65,600	8,800	4,000	4,800
Resto del País	61,900	8,300	450	7,850
TOTAL	1,080,300	145,000	43,500	101,500 (*)

*Includes residences in other zones.

SOURCE: La Electrificación en Colombia, Informe 1979-1980. Ministerio de Minas y Energía, Instituto Colombiano de Energía Eléctrica.

Total cost of the PNER is estimated at US$150 million based on a cost per residence of US$1000. Financing for the Plan will come from the following sources:

External Credit	US$50.0 million
National Budget	US$33.0 million
Agricultural Credit Bank	US$22.5 million
National Coffee Growers Federation	US$22.5 million
ICEL	US$4.0 million
Utilities	US$13.5 million
Users	US$4.5 million

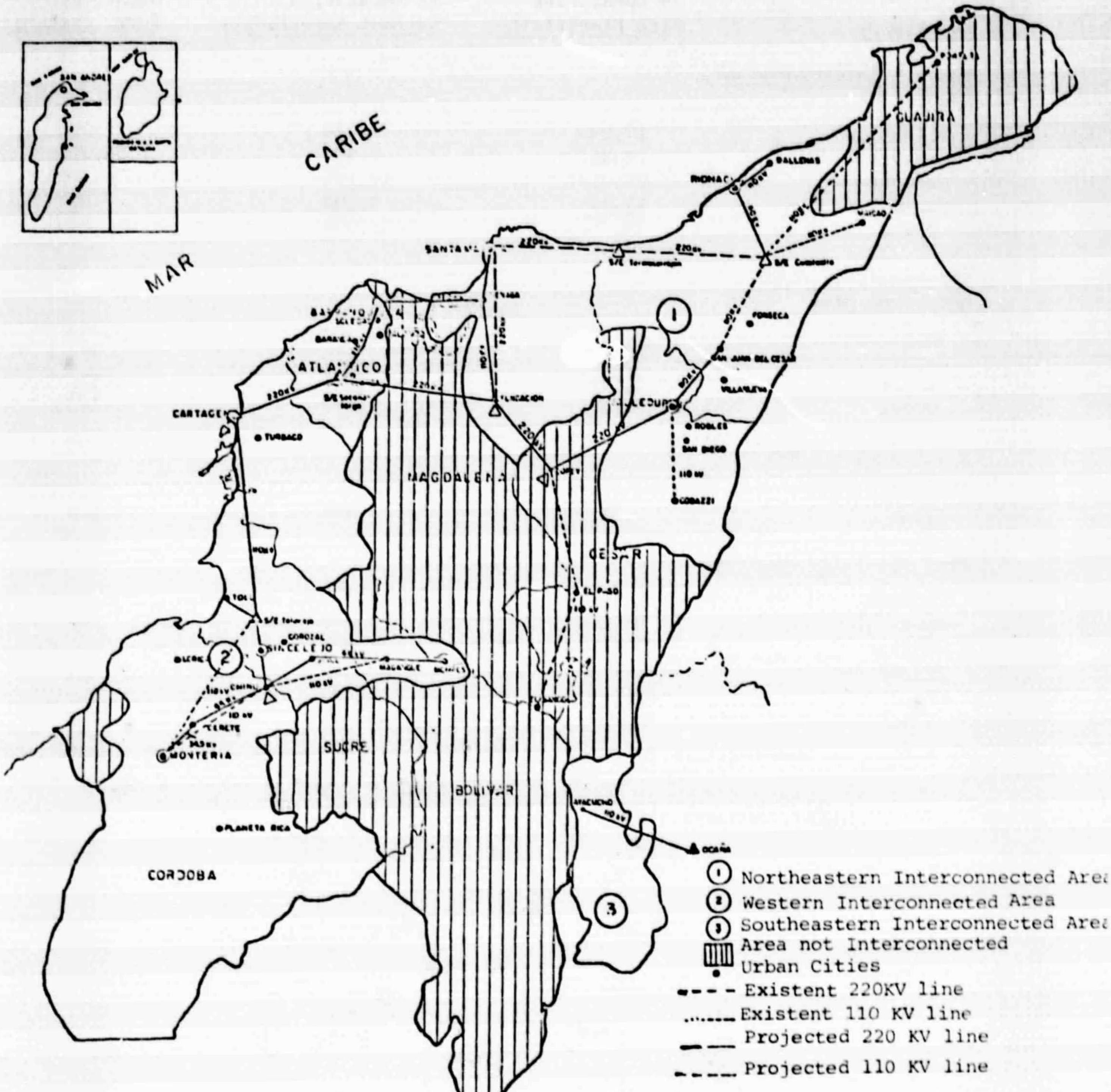
In addition to the PNER, several other programs are providing electricity to rural areas. Within the Integrated Rural Development program (DRI), the Electrification project will provide electricity to 40,000 rural users in the departments of Boyacá, Santander, Cauca, Nariño, Cordoba, and Sucre. As of 1980, 18,946 rural users had been provided a total of 16,247 KVA at a cost of US$7.24 million. Total cost of the project is estimated at US$25 million. Since 1972, ICEL has also provided US$2 million in loans for Rural Electrification to utilities through the National Rural Electrification Financing Fund (FFNER). Finally, several of the larger regional utilities, such as Electric Energy Company of Bogotá (EEEB), Public Utility of Medellín (EPM), and Regional Utility of the Valley of Cauca (CVC), have ambitious rural electrification programs of their own.

One of the most extensive rural electrification projects currently underway is the Regional Rural Electrification Program for the Atlantic Coast and San Andres (PERCAS) under the auspices of CORELCA. As seen in Figure 3.1 large regions of the Atlantic Coast are not interconnected with the CORELCA grid, but receive electricity from diesel generators and other independent sources. The extent of rural electrification in the interconnected and non-connected regions of the Atlantic Coast is presented in Table 3.3.

Through the PERCAS effort 58,200 residences currently without electricity and 104,040 residences with partial or deficient service will be fully covered, as indicated in Table 3.4. As a consequence of grid extension, 38MW of installed diesel will be replaced. This includes 19MW which will be provided to agro-industries in two stages 1981-1985 and 1984-1988 at a total cost of US$150 million. The World Bank recently granted a US$36 million loan to Colombia for this project.

FIGURE 3-1.

ELECTRIC NETWORK OF THE ATLANTIC COAST AND SAN ANDRES



SOURCE: Programa Regional de Electrificación Rural-Costa Atlantica y San Andres, CORELCA, Enero, 1981.

TABLE 3.3

ELECTRICAL COVERAGE IN THE ATLANTIC COAST REGION

Department	Rural Residences in Localities With Electricity	Rural Residences In Localities Without Electricity	Number of Rural Customers
Western Interconnected Area			
Atlantico	17,800	1,720	16,900
Bolivar	24,850	7,380	18,360
Córdoba	25,050	17,170	16,560
Sucre	11,600	8,800	7,020
TOTAL	79,300	35,070	58,840
Northeastern Interconnected Area			
Magdalena	9,060	2,400	4,640
Cesar	7,650	1,820	2,750
Guajira	3,990	2,840	1,590
TOTAL	20,700	7,060	8,980
Southeastern Interconnected Area			
Cesar	7,015	1,430	6,530
Area Not Interconnected			
Córdoba	240	1,590	
Sucre	4,760	4,440	
Bolivar	9,450	15,650	
Magdalena	10,410	21,250	
Cesar	12,070	6,430	
TOTAL	36,930	49,360	

SOURCE: Programa Regional de Electrificaión Rural - Costa Atlantica y San Andres, CORELCA, ENERO, 1981.

TABLE 3.4

COVERAGE OF PERCAS BY DEPARTMENT

	Residences		Persons	
	Expansion[1]	Extension[2]	Expansion	Extension
Atlantico	16,660	800	106,700	5,120
Bolivar	19,940	9,560	127,715	61,230
Cesar	22,270	5,680	142,640	36,380
Cordoba	17,600	20,750	112,730	132,900
Guajira	1,220	660	7,810	4,230
Magdalena	14,600	8,060	93,510	51,520
San Andres	140	205	895	1,310
Sucre	11,610	12,490	74,360	80,000
TOTAL	104,040	58,205	666,360	372,790

1. Replacement and expansion in localities currently with service, including interconnected areas and areas with partial service from independent generation sources.

2. Extension of service to localities not presently electrified.

SOURCE: Programa Regional de Electrificación Rural-Costa Atlantica y San Andres.

3.3 Agricultural Development Plans

Colombia's agricultural sector is characterized by a dual economy: the large export-oriented modern sector and the largely unmechanized traditional "minifundio" sector. During most of the post-war period, agricultural development in Colombia concentrated on expanding the export sector to generate foreign exchange. In 1961 an effort was begun to address this inequity through the creation of INCORA, the Colombian Institute of Agrarian Reform. INCORA's tasks included land redistribution, agricultural extension, training of farmers, irrigation, credit and social assistance. Nonetheless agricultural production continued to increase much more rapidly in the commercial sector than in the traditional sector. Furthermore, population growth led to increases in rural unemployment. Under the Lopez Michelson government, 1975-1978, the Plan "Para Cerrar la Brecha"[1] was introduced which emphasized redistribution of income to benefit the small farmers of the traditional sector.

As part of this plan, the Integrated Rural Development Program (DRI) was initiated in 1976 to improve the welfare and productivity of small farmers (minifundistas). For the purposes of the program, minifundios were defined as farms of less than five hectares; approximately 83% of all farms according to the 1970-71 Agricultural Census. The National Planning Department (DNP) identified 92,000 farms in eight departments[2] which are to benefit from the program during the five year period 1977-1981. Thirteen government ministries and agencies are charged with carrying out development activities in DRI's three major program areas: production, infrastructure and social welfare, as illustrated in Table 3.5.

Table 3.6 indicates that planned DRI expenditures between 1979 and 1982 total about US$428 million. About US$100 million is in the form of credit from the Caja Agraria which will be recovered. Some 60% of total spending will be channeled to directly productive activities, 22% to infrastructure, 16% to social welfare and 2% to administration. Approximately 40% of the cost is being financed by foreign credit, chiefly through the Inter-American Development Bank, the World Bank and the Canadian International Development Agency.

After the completion of the first stage, the DNP plans to extend DRI to an additional nine departments.[3] During the two stages DRI will cover a

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[1] To close the Gap.

[2] Nariño, Cauca, Cundinamarca, Antiquia, Cordoba, Sucre, Boyacá and Santander.

[3] Huila, Tolima, Caldas, Meta, Norte de Santander, César, Bolivar, Magdalena and Atlántico.

total of 157,000 farm families directly through the provision of technical assistance, credit, training, and marketing assistance. Furthermore, 628,000 families will benefit indirectly through the provision of infrastructure and the satisfaction of basic needs.

TABLE 3.5

DRI ORGANIZATIONAL CHART

PROGRAM	EXECUTING ORGANIZATION
Production	
Credit	Caja de Crédito Agrario
Technological Development	ICA
Marketing	Central de Cooperativas de la Reforma Agraria (CECORA)
Organizational Training	Servico Nacional de Aprendizaje (SENA)
Natural Resource Conservation	INDERENA
Infrastructure	
Neighborhood Roads	Fondo Nacional de Caminos Vecinales
Rural Electrification	ICEL and Regional Utilities
Social Welfare	
Rural Aqueducts	Instituto Nacional de Salúd - INS
Education	Minístерio de Educacion Nacional and Instituto Colombiano de Construcciones Escolares (ICCE)
Health	Ministério de Salúd, Instituto Colombiano de Bienestar Familiar and Fondo Nacional Hospitalário

SOURCE: Plan de Integración Nacional 1979-1982, Tomo I. Departamento Nacional de Planeación, Bogotá, 1980.

TABLE 3.6

Planned DRI Expenditures 1979-1982

(millions of US dollars)

Year	Total	Production[1]	Infrastructure[2]	Social Welfare[2]	Administration
1979	55.0	31.7	12.9	9.0	1.4
1980	70.8	48.9	12.0	8.4	1.5
1981	119.9	69.6	27.0	20.2	3.1
1982	182.7	104.2	44.2	30.0	4.5
TOTAL	428.4	254.3	96.1	67.6	10.4

1 Includes recoverable credit.
2 Includes funds provided by local communities

SOURCE: Plan de Integración Nacional 1979-1982, Tomo I.

4.0 FINANCING OF AGRICULTURE AND DEVELOPMENT PROJECTS

4.1 Overview of the Colombian Banking

The Banco de la Republica (Bank of the Republic) is Colombia's central bank which carries out the functions of issuing currency, rediscounting loans for member banks, and carrying out the monetary and banking policies set by the Monetary Board. Until 1973 the bank was partly owned by private banks, but at that time the State took over 99% of the capital, thereby nationalizing it. The Bank of the Republic guarantees government loans and makes loans available to official and semi-official institutions. Furthermore, it operates several specialized funds that serve as important sources of credit to the private sector. These include the Fondo Financiero Industrial (Industrial Finance Fund), Fondo de Inversiones Privadas (Private Investment Fund), Fondo Financiero de Desarrollo Urbano (Urban Development Finance Fund) and the Fondo Financiero Agropecuario (Agriculture and Livestock Finance Fund).

The Private Investment Fund, established in March 1963, is financed by loans from international agencies and foreign governments and provides credit for agricultural, mining and industrial projects that have been refused regular bank financing. The Industrial Investment Fund, similar to the Private Investment Fund, finances working capital and new investments of small and medium-sized firms manufacturing capital goods that compete with imported products. The Agriculture and Livestock Finance Fund supplies supervised credit for growing specific crops. The fund receives its resources from the compulsory sale of agrarian development bonds to commercial banks. Each farmer who receives credit from this fund must follow an investment plan developed by fund specialists for his needs. The Urban Development Finance Fund, created in 1968, finances only self-liquidating public works projects of municipalities.

Another large government-owned bank is the Caja de Crédito Agrario, or Caja Agraria, created in 1931 to serve the rural sector. The Banco Ganadero and Banco Cafetero are mixed banks with government and private participation which cater to the livestock and coffee sectors in particular but which make loans in other agricultural areas as well. Finally, the Fondos Ganaderos (Livestock Funds) are joint-stock companies set up by local government jurisdictions and private companies.

Development banks include both the government-owned Instituto de Fomento Industrial (Industrial Development Institute) and the private development finance corporations (financieros). The development banks provide a large

percentage of the medium and long-term capital for industrial firms. The private development banks have also been an important channel for foreign investment funds.

As of 1979 there were 29 commercial banks in the country, seven of which had been foreign-owned. Under Law 055 of 1975, all existing foreign-owned banks had three years to become at least 51% Colombian-owned. In addition no new foreign banks were permitted to enter the country. Most commercial loans to business and industry are short term (up to one year) but can often be renewed. As of December 31, 1976 only short term credit is available to foreign companies operating in Colombia. In order to alleviate Colombia's chronic credit shortage, the Lopez Michelson government permitted insurance companies to make short-term loans and to invest in corporate stock, which they had previously been prohibited from doing.

Credits to the external sector include both import and export financing. Import financing comes both from local banks and from resources generated by trade agreements between Colombia and other countries. The Fund for the Promotion of Exports (PROEXPO) is a government entity established to increase Colombia's exports by providing credit to exporters, researching foreign markets, offering financing to foreign buyers and providing insurance to cover non-payment by foreign buyers.

4.2 Agricultural Financing

Approximately three-fourths of all agricultural credit is supplied by various state lending institutions, and one-fourth by private commercial banks and the large grower's associations, such as the National Federation of Coffee Growers. By law commercial banks must lend at least 15% of their deposits to farmers. Despite the numerous sources of government funding for agriculture, it is estimated that half of all farmers have no access to credit.[1]

As indicated in Table 4.1, the principal source of institutional credit in the Colombian agricultural sector is the Fondo Financiero Agropecuario (Agriculture and Livestock Finance Fund). Since the enactment of the Ley V (Fifth Law) in 1973, the Fund has been authorized to rediscount agricultural loans made by government and private financial institutions. Under the Ley V, short-term loans of up to two years are made available for working capital, medium-term loans of two to eight years for depreciable investments, low yield crops, non-cattle livestock rearing and acquisition, and long-term loans of eight to fifteen years for low return investments, cattle rearing and

[1] According to Caja Agrario.

TABLE 4.1

INSTITUTIONAL CREDIT FOR THE AGRICULTURAL AND LIVESTOCK SECTORS 1980-81

(US$ millions)

Institution	1980[1]	1981[2]
Fondo Financiero Agropecuario	477	645
Caja Agraria	245	241
Incora	12	14
Banco Ganadero	23	36
Fondos Ganaderos	5	14
TOTAL	762	950

[1] Preliminary estimates of disbursements. Average CY-1980 Exchange Rate: 47.45 Pesos = US$1.

[2] Program of Credit for CY-1981

SOURCE: Colombia: Annual Agricultural Situation Report. American Embassy, Bogota, January 21, 1981.

integrated dairy or beef cattle projects. Interest rates, rediscount rates and rediscount margins for selected agricultural loans under Ley V are presented in Table 4.2 In addition, Table 4.3 shows the amount of credit approved in 1980 under Ley V by type of activity.

The Ley V represents an attempt to rationalize agricultural credit on an economic basis. All agricultural loans financed by the Agriculture and Livestock Finance Fund under Ley V must be accompanied by an approved investment plan. Each lending institution, such as the Banco Ganadero, has a staff of qualified professionals including agronomists, agricultural economists and veterinarians who work with the farmer to develop an investment plan which meets his needs and is financially sound. The farmer agrees to finance 20% of the total investment and the bank provides the remaining 80%. The bank technicians are responsible for visiting the farm to insure that the investment plan is being carried out as scheduled. Failure to follow the plan can lead to immediate termination of the loan and full repayment to the bank. Failure to make scheduled loan installments results in a fine of twice the interest rate of the loan on the balance due, not to exceed 36%.

Collateral varies according to the loan term and the financial state of the borrower. For long-term loans, a farm of home mortgage guarantee is generally required. In the case of medium-term loans, farm equipment and cattle are accepted as collateral. For short term loans personal guarantees, cosigning and farm equipment collateral are common arrangements, depending on the financial solvency of the borrower.

The 866 branches of the Caja Agraria seek to serve the credit needs of Colombia's peasant farmers. About 70% of the Caja's resources are directed towards small farmers and 30% to medium-size farmers. Small farmers are classified as those whose total assets do not exceed US$36,000. It is not possible to classify farmers according to farm size for credit purposes because farm value varies greatly according to crop. Short term loans are provided to small farmers of subsistence crops such as potatoes, corn and cassava at 18% interest. Most loans are for seed and fertilizer and the loan is repaid after the harvest. Average loan size for small farmers is US$840. The Caja also provides longer term credit for rural electrification, housing, small agroindustries and handicrafts.

TABLE 4.2

SELECTED LEY V AGRICULTURAL CREDIT - 1981 TERMS

Activity	Loan Term	Interest Rate to Borrower	Rediscount Rate
Cattle Fattening	1 yr.	24.0%	23.5%
Subsistence Crops	1-2 yrs.	18.0%	12.0%
Poultry (layers & broilers)	1-2 yrs.	21.0%	17.7%
Working Capital 1/	1-2 yrs.	24.0%	19.3%
Sugar Cane	2-8 yrs.	21.0%	18.5%
Irrigation and Land Improvement	2-6 yrs.	21.0%	18.5%
Agricultural Machinery	4-6 yrs.	21.0%	18.5%
Integrated Livestock Raising Plan (including machinery)	2-8 yrs 2/	20.0%	17.9%
Reforestation	8-15 yrs.	15.0% 3/	12.0%
Deep wells (with or without equipment)	8-15 yrs. 4/	21.0%	18.5%
Sowing of fruit trees	8-15 yrs. 4/	21.0%	18.5%

1/ Special line of credit for farmers with liquidity problems - especially for purchase of seeds, vaccines, fertilizer, etc.

2/ Maximum loan US$88,000.

3/ 3% accumulated over loan life and 12% deferred

4/ 4 years grace period and farm or home mortgage as collateral for all long-term loans

SOURCE: "Servicios del Banco Ganadero", Banco Ganadero, Subgerencia de Fomento, Bogotá, Colombia.

Table 4.3

SUMMARY OF CREDIT APPROVED UNDER

LEY V - 1980[1]

ACTIVITY	LOANS APPROVED (millions of US$)
Crop Sowing and Maintenance	42.7
Livestock	95.9
Infrastructure	38.0
Construction of Deep Wells	2.1
Peasant Housing	.6
Agricultural Machinery	24.0
Purchase of Farms by Agricultural Professionals	3.6
TOTAL	207.2

[1] Not including semi-annual crops

SOURCE: Fondo Financiero Agropecuario, Departmento de Credito Agropecurio.

4.3 Attitudes of Financial Institutions Towards Photovoltaics

Interviews with several financial institution representatives were held to assess the attitudes of the financial sector towards photovoltaic systems. Awareness of photovoltaics in the financial sector was generally low, particularly with regard to possible applications. Government agricultural credit banks were generally enthusiastic about the potential for replacing diesel generators with PV arrays. In particular, representatives of the Banco Ganadero foresaw great potential in using PV for cattle watering in the Eastern Plains region of Colombia where they felt it might be competitive with diesel. They noted that Ley V credit currently available for the purchase of diesel generators could be made available for the purchase of PV arrays. The applicable interest rate for agricultural machinery is 21% with a maximum loan term of six years. However, a representative of the Caja Agraria was much less enthusiastic, noting that although the majority of the Caja's clients lack electricity, they have much more immediate and less expensive needs. This is corroborated by the fact that the Caja's average loan to the small farmers is US$840. Other factors unfavorable to PV mentioned by various sources include:

- high initial capital cost of photovoltaic systems
- belief that for most remote locations diesel generators or mini-hydro systems would be more economical that PV
- government policy of replacing diesel generators through grid extension
- traditional conservatism of Colombia agricultural sector and reluctance to use new technologies
- preference for financing projects which use established technologies

4.4 Availability of Financing for Photovoltaic Systems

The availability of financing for photovoltaic systems in Colombia is difficult to estimate. If PV equipment qualifies under Ley V for the same financing that currently applies to diesel generators, as indicated by the Banco Ganadero representative, then the number of farmers able to purchase PV systems would increase. Table 4.3 indicates that about 24 million dollars was lent for the purchase of agricultural machinery under Ley V in 1980. Assuming that PV can be demonstrated to be cost-competitive with diesel for rural areas, then perhaps 10% or 2.4 million dollars in loans could be made available for PV purchases.

However, if PV is not eligible for Ley V financing, then market rates of interest (i.e., 30-35%) would prevail. This would limit PV purchases to only very wealthy landowners. Furthermore, it would adversely affect the economics of PV systems compared to diesel generators or other alternatives.

5.0 BUSINESS ENVIRONMENT

5.1 Level of Awareness

The level of awareness of photovoltaic systems in Colombia is generally low. An estimated 20-25% of the individuals contacted by the team had any substantial knowledge of PV systems. Many contracts confused PV systems with solar water heating systems, which are becoming well-known in Colombia due to the work of the Centro Las Gaviotas. Dr. Paolo Lugari, Director of Centros Las Gaviotas, asserted that commercialization of PV in Colombia will be difficult because it is not a known technology. He believes that PV demonstration projects are needed to convince Colombians of the feasibility of the technology. He believes that PV demonstration projects are needed to convince Colombians of the feasibility of the technology.

Among government officials involved in energy planning, understanding of PV technology and possible applications is widespread. Furthermore, there is a general recognition that stand-alone systems are the only answer to electrification needs in remote areas, and an aversion to further use of diesel generators due to maintenance problems and high fuel transport costs. However, several DNP and ICEL officials expressed reluctance towards PV due to its high first cost and a preference for mini-hydro systems for remote electrification.

Agriculture sector officials were generally aware of photovoltaics but not of possible agricultural applications. ICA, FEDEGAN and Banco Ganadero officials were enthusiastic about the possibility of using PV for livestock watering in remote regions such as the Eastern Plains. These individuals claimed that livestock owners represent a large potential private market for PV because they have the capital to invest in PV equipment and need electricity for both water pumping and domestic uses.

Colombian government entities which have expressed interest in photovoltaics include:

- TELECOM--installation of 72Wp radio telephones
- Empresas Departmentales de Antioquia--PV powered telephone centrals and UHF television receivers
- INTRAVISION--installation of 6-7kw television receivers in 10 mountainous locations
- AEROCIVIL--installation of 5kw air navigation signals in 6 mountainous areas

- Dirección Marítima y Portuaria--17 PV-powered buoys for maritime signalling
- Ministry of Health--"SEM"--Malaria Eradication Service--PV-powered vaccine refrigerators
- ECOPETROL--Cathodic protection

5.2 PV Business Activity in Colombia

Photovoltaic marketing in Colombia has increased recently due to Telecom's purchase of PV equipment for rural telephone communications. Based on the best information available to the team, eight firms, three of which are Americans, are currently marketing photovoltaics in Colombia. The non-American firms include the German AEG-Telefunken and Messerschmidts, the Dutch firm Phillips and the Japanese firms SHARP and SANYO. Dr. Lugari of the Centro Las Gaviotas noted that Japanese firms such as SHARP and SANYO have been more willing to set up photovoltaic demonstrations than either U.S. or European firms. He asserted that dealing with American firms has typically involved delays and excessive paperwork.

Current photovoltaics marketing activity appears to be centered on the Colombian government, and in particular, TELECOM. After installation of PV equipment by Lucas Energy Systems under the first phase contract is completed in 1982, TELECOM plans to submit a solicitation for an additional 2200 PV-powered rural telephone systems. PV panels used by Lucas Energy Systems in the first phase were provided by ARCO Solar. TELECOM has requested Inter-American Development financing for the second phase of the project.

5.3 Current Generation Equipment Competition

Diesel generators have been used widely in the past in Colombia to provide electricity for remote locations. Since electrical generators are not manufactured in Colombia the equipment has been imported from abroad. Imports of generator sets totalled US$21.56 million in 1979 and US$14.41 million in 1980. According to U.S. Department of Commerce statistics, U.S. exports of diesel engine driven generator sets of less than 400 kw in 1980 amounted to US$4.87 million. Exports of gasoline engine generators of less than 5 kw totalled US$259,322 and those of over 5 kw totalled US$126,108.

Although detailed information of sales of diesel and gasoline generators by company in Colombia is not available, a census done by the Administrative Department of Intendencies and Commissaryships (SAINCO) provides useful data on the makes of electrical generators used for power

supply in the unelectrified eastern region of Colombia. As seen in Table 5.1 Lister Blackstone diesel generators are most prevalent in the 0-5 and 5-10 kw range, Lister Blackstone and GM Detroit Diesel in the 10-50 kw range, and GM Detroit Diesel, Lister Blackstone, MAN, and Skoda in the over 50 kw range.

A similar survey undertaken by CORELCA for the Atlantic Coastal region as part of its PERCAS program identified 95 diesel generators of greater than 50 kw to be replaced by grid extension. A breakdown of these 95 generators by manufacturer revealed the following distribution:

General Motors	34.7%
MTU	24.2%
Caterpillar	12.6%
MAN	8.4%
Lister	5.2%
Cummins	4.2%
Mercedes Benz	4.2%
Roman	4.2%

For the size range of generators with which PV would most likely compete (i.e., 1-10 h.p.), commonly used makes in Colombian agriculture include Briggs & Stratton, Kohler, Delco and Yamaha. Prices for several Yamaha gasoline generators are given below:

Power Rating	Price (1981 dollars)
500 watts	810
1500 watts	1270
1800 watts	1460
2600 watts	1770

5.4 Climate for Investment in Photovoltaics

No incentives currently exist in Colombia for either the purchase of, or investment in, photovoltaics. However, Dr. Tomas Held, President of the Colombian Solar Energy Association noted that approval of tax incentives for installation of solar water heaters is likely this year, after several years of lobbying. Therefore, as PV becomes a more familiar technology in Colombia, it may follow this example.

Several contacts expressed the belief that PV sales in Colombia would increase if a foreign company established an assembly operation in the country. Most balance of system components, such as batteries, glass, wiring, etc. are produced in Colombia so that a joint-venture arrangement seems feasible. However, many Colombian firms are rich in engineering

TABLE 5.1

DISTRIBUTION OF EXISTING DIESEL GENERATORS BY MANUFACTURER
IN THE INTENDENCIES AND COMMISSARYSHIPS OF EASTERN COLOMBIA

	GENERATOR CAPACITY			
Generator Manufacturer	0-5 KW	5-10 KW	10-50 KW	50 KW
GM Detroit Diesel			22	22
Caterpillar			2	7
MWM[1]			1	1
Lister Blackstone	9	32	69	23
MAN[2]				13
Ruston[3]			6	
Bolinder			4	
SLM-Oerlikon[4]				2
Skoda-Mez[5]			11	12
Yanmar[6]	1			
Honda			3	
Onan	1	1	1	
Pegasso[7]				1
Sulzer[8]				2
MTU[9]				3
Dorman[10]			1	
Continental		1	1	
Peter McLaren			1	1

1/ Motor-Werke Mannheim AG (West Germany)
2/ Machinen Fabrik Augsburg - Nurnberg AG (West Germany)
3/ Ruston Diesel Ltd (UK)
4/ Switzerland
5/ Skoda Compressor Sets (Czechoslovakia)
6/ Yanmar Diesel Engine Ltd. (Japan)
7/ Pegasso E.N.D.S.A. (Spain)
8/ Sulzer Brothers Ltd. (Switzerland)
9/ Motoren-und-Turbinen Union Friederichshufen Gmbh (West Germany)
10/ Dorman Diesels Ltd. (UK)

SOURCES: Evaluacion Plan Trienal, Inventorio Plantas Electricas Diesel y Consumo de Combustible y Aceite. DAINCO, Division de Infraestructura, Sección Energía, Mayo 22 de 1981.

expertise and skilled workers, yet capital poor. Therefore, U.S. firms would probably have to provide most of the initial capital for such a venture. More detailed information regarding foreign direct investment in Colombia can be found in Appendix B.

It is also important to note that Colombia's economy is characterized by relatively high inflation, high interest rates, and a steadily depreciating exchange rate. These factors lead Colombian investors to prefer quick returns on their investment of at least 30-35%. Therefore, PV may not interest many Colombian private investors because of the long payback period (about 10 years) usually associated with it.

5.5 Tariff Rates and Import Restrictions

The Colombian tariff schedule consists of an eight digit numerical sequence. The first four digits correspond to the Brussels Tariff Nomenclature (BTN) while the last four correspond to the Andean Common Market nomenclature known as NABANDINA. Import duties consist of specific duties based on weight measured in kilograms for some products, and ad valorem duties based on the normal price in the country of origin plus transport charges, insurance, packing and all necessary expenses incurred in bringing the merchandise into Colombia (CIF value) for other products. Table 5.2 lists tariff classifications, tariffs, sales tax rates and amount imported for various products of interest to the American photovoltaic exporter.

As can be seen in Table 5.2, imported American photovoltaics are assessed with a 10% tariff on the CIF price plus a 6 percent sales tax on the CIF price.[1] It should be recognized that this rate applies only to the cells themselves. Imported photovoltaic systems face a tariff equal to the highest tariff applicable to any component part (i.e., 35% for batteries). Therefore, the U.S. manufacturer should ship balance of system components separately in order to avoid paying this higher rate on the entire PV system.

All imports must be registered with the Institute of Foreign Trade (INCOMEX). For some goods a prior import license is required. Colombia maintains a system of preferential tariff rates for eligible imports from

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[1] In addition, most imports are assessed the following surcharges: 5% of CIF value for the Export Promotion Fund, 1.5% of CIF value for the Coffee Promotion Fund, and 1% of f.o.b. value for the Consular Invoice.

TABLE 5.2

COLOMBIAN TARIFFS AND VOLUME OF IMPORTS FOR SELECTED PRODUCTS

Product	Tariff (cif value)	Sales Tax (cif value)	Amount Imported 1979 (US$fob)	Amount Imported 1980 (US$fob)	Tariff Classification
Photovoltaic cells	10%	6%	316,752	196,971	85.21.11.00
Windmills	30%	6%	5,823	46,618	84.08.89.02
Generator sets[1] 10.5 kw	50%	6%	117,914		85.01.03.01
Generator sets[1] 0.5-100kw	50%	6%	3,970,920		85.01.03.02
Other Generator sets[1]	5%	6%	17,471,978		85.01.03.99
Generator sets 0.5-18.5kw				12,356,760	
Generator sets 18.5-30kw				120,459	
Other Generator sets[1]				1,938,296	
Centrifugal pumps 4"	20%[2]	exempt	2,547,975	1 140,069	84.10.04.01
Centrifugal pumps 4-8"	45%[2]	exempt	2,157,765	1,643,054	84.10.04.99
Lead Acid batteries 500 ampere hrs.	35%	6%	1,533,577	1,167,921	85.04.01.01
Other lead acid batteries	30%	6%	Unknown	1,481,740	85.04.01.99
Nickel Cadmium batteries	35%	6%	693,888	405,675	85.04.89.00

1/ Classification changed July 1980

2/ No tariff for Andean Pact

SOURCE: "Arancel de Aduanas, Indice Alfabetico"; INCOMEX, 1980.

Andean common market (ANCOM) and Latin American Free Trade Association (LAFTA) countries. Tariffs are highest on those products which are manufactured domestically or are considered luxury items. For further information regarding trade regulations see Appendix B.

5.6 Standards and Regulations

The Colombian Electric Energy Institute (ICEL) has written a Technical Standard Manual, used by its subsidiaries and affiliates as well as other electric utilities, which provides detailed specifications for all components of transmission and distribution systems. In addition, the Colombian Technical Standards Institute (ICONTEC) has developed standards for all residential, commercial and public lighting installations. These specifications, which are based on U.S. electrical standards, are implemented through the electric utilities and local manufacturers and importers. Primary electric power is 13,200 V with a secondary power distribution of 220/110 V and 60 hertz.

The Colombian Institute of Foreign Trade (INCOMEX) does not require specific technical standards for any imported product unless specified by ICONTEC for imports made by Colombian government entities by means of international bidding. However, the metric system became obligatory in September 1976. Certain Spanish weights are also still in use, especially in rural areas. These include the arroba (1 arroba = 27.5 pounds) and the quintal (1 quintal = 101.43 pounds). Furthermore, the rural land measure fanegada (80 meters x 80 meters) and the urban land measure vara (80 cm x 80 cm) are used in some parts of Colombia.

5.7 Conclusions

The Colombian market presents both advantages and disadvantages for the American photovoltaic manufacturer. The principal advantages are:

1) Large percentage of rural population without electricity
2) High cost of grid extension
3) Maintenance and fuel supply problems associated with internal combustion engine generators
4) Availability of long-term financing through Ley V if PV can be proved to be cost-competitive

Against these factors the following disadvantages must be weighed:

1) Unfamiliarity with PV, especially in rural sector
2) Government preference for mini-hydro systems for electrification of remote areas

3) Large hydroelectric potential

4) Reluctance of agricultural sector to use new technologies

5) Foreign PV competition

6) Lack of incentives for use of or investment in photovoltaics

In order to maximize the photovoltaic market potential in Colombia, U.S. firms should:

1) Offer complete systems (e.g., PV-powered water pumps, refrigerators, etc.)

2) Perform as much as possible of the production and assembly of PV systems in Colombia or another Andean Pact country to avoid higher tariffs

3) Consider forming a corporation under Colombian law with majority Colombian participation to take advantage of ANCOM's liberal trade policy and open up markets in other member nations.

6.0 FEASIBLE PHOTOVOLTAIC APPLICATIONS

The purpose of this chapter is to describe PV applications in Colombia that were found to be technically and economically feasible. This information is then used to estimate the potential PV market size in the 1981-86 timeframe.

Technical feasibility was judged in terms of the suitability of the load characteristics, use profile and operating environment to PV use. Applications that require low power levels, minimal battery capacity, stable year-round energy demand and an environment detrimental to conventional power sources were considered most suitable for PV application. Economic feasibility was based on comparing the life-cycle costs of a PV system to that of a conventional gasoline or diesel power system. Since PV system costs are declining and energy costs from conventional systems are increasing, at some point in time the costs will be equal. An application is considered economically feasible for this study if cost-competitiveness is reached prior to 1986.

After that year, PV cost reduction expectations will make them economically competitive with grid electricity, thus opening up a vast new market for PV. The cost and technical parameters used to evaluate potential applications are shown in Table 6.1.

The market estimation procedure used is based on the premise that a market will start developing when PV systems are cost-competitive, on a life-cycle basis, when compared to the least cost, practical alternative. At this point, the market share for PV will be close to zero as the conventional systems have the advantages of existing supply and repair infrastructure, tradition, and less initial capital investment. Once the cost equality point is passed, their rate of penetration will be determined by market-related factors. Another assumption made is that PV systems will have greatest acceptance by those currently using conventionally powered equipment. The bound on the market is estimated to be the peak power required for the total number of cost-competitive, practical applications. The upper bound is then adjusted by a subjectively determined market penetration rate to obtain the 1981-86 market size. The penetration rate is determined by factors such as: level of awareness, first year of cost-competitiveness, financing availability and institutional barriers/ incentives.

Table 6.1

Cost and Technical Paramaters Used in Cost-Competitiveness Analysis

Discount Rate (%)	12
Analysis Life (years)	20
Fuel Cost - Gasoline ($/gallon) Diesel	0.88-2.25 0.70-1.75
Real Fuel Cost Escalation %	5
Life of Conventional System (years)	5-10
Labor Cost ($/hour)	2.00-3.00
Battery Life (years)	5
Battery Cost ($/AH)	1

	J	F	M	A	M	J
Solar Insolation (langleys/day)	450	445	420	375	370	350
	J	**A**	**S**	**O**	**N**	**D**
	380	410	430	360	390	390

Average Insolation (langleys/day) 398 ± 33 (std. dev.)

	1980	1982	1984	1986
PV system cost $/Wp without batteries (includes a 10% CIF surcharge over JPL cost projections)	18.89	8.86	6.56	4.26

Note: All costs are measured in 1980 dollars, and discount and fuel escalation rates are measured after factoring out inflation.

The following applications are discussed in the remainder of this chapter:

- coffee sector uses
- cattle watering
- rural water supply and irrigation
- rural telephone
- rural health posts and health centers
- rural domestic uses

6.1 Coffee Sector

6.1.1 Sector Characteristics

Coffee is by far the most important export product for Colombia. In 1980, coffee accounted for 61% of Colombia's export earnings. About 20% of the country's planted land is devoted to coffee.

Colombia's Ministry of Agriculture reports a total harvest for 1980 reaching 3.53 billion kilograms of coffee berries for a production of 762 million kilograms of coffee. While coffee grows throughout Colombia, the most productive regions are in the mountain slopes of the central highlands. The departments of Antioquia, Caldas, Tolima, Valle, Risaralda, Quindio and Cundinamarca produce almost 80% of the total, which is grown on 1.75 million hectares (Table 1 in Appendix C).

Coffee is harvested throughout the year although there are major and minor harvests occurring at different times, depending on the region (Table 2 in Appendix C).

6.1.2 The Process

Coffee berries are picked by hand during the day. In the evening, the meat or pulp is removed on mills and the bean with the remaining pulp is allowed to ferment overnight. The following day the coffee is washed and classified and the drying process begins.

Approximately 55% of the harvest is dried mechanically in silos using diesel oil to provide heated air and electrical blowers to move the air. Mechanized drying is not common except on large farms. The de-pulping process, as well as the fermentation and drying, is done at the farms where the coffee is picked. De-pulping mills are driven manually, with electric motors or with small gasoline engines. It is estimated that in excess of 1% of the national fuel oil consumption goes into the drying of the coffee beans in the larger farms. The remaining 45% of the coffee is air dried using a variety of

techniques to enhance drying by exposing the beans to the sun. Once the coffee is dry it is taken to central mills for the final milling, classification and marketing.

Although coffee farm sizes vary considerably, the average is about 12 hectares with a production of 48,000 kilograms of coffee berries per year. There are an estimated 16,500 farms of this size.

6.1.3 PV Application Possibilities

A) Coffee De-pulping

The coffee-producing areas of Colombia, being in the Central Mountain Ranges, are electrified, deriving their electrical energy mostly from hydroelectric installations. It is estimated, though, that as many as 10% of the smaller farms lack electrical energy to power their de-pulping equipment. At the farm level, then, it is possible that photovoltaic equipment could become an alternative to gasoline powered engines. There would be a further advantage if the PV system could also satisfy domestic electricity needs where electrical service is lacking.

The typical installation, which PV systems could power, uses a 2 HP gasoline engine. The capacity of this de-pulping equipment is about 400 kilograms of coffee berries per hour. It is estimated that as many as 8,000 such systems are in operation, but the average use is only about 120 hours/year (Table 3 in Appendix C). While these small de-pulping machines use 2 or 3 HP engines, the actual requirements are in the order of 0.75 to 1 HP. Larger engines are used just because they are available. In fact, a vertical drum type de-pulping machine has recently been developed and is now being marketed. It processes about 1,000 kgs/hour and uses a 0.5 HP electric motor. The actual power requirement is listed as 0.36 HP.

It is important to realize that present practices call for the de-pulping operation to be done late in the day, and as soon as possible after the berries are picked. This would call for PV systems with storage batteries capable of delivering from 0.5 to 1.5 kwh/day.

Systems installed for de-pulping coffee berries would also be used for general electric needs and could be used to power fans to enhance coffee drying.

B) Coffee Bean Drying

The proper drying of the coffee bean is an important factor affecting the quality of the product. Due to technological advances, the production of

coffee per unit land has more than doubled in the last decade. This increased production has demanded new and improved drying techniques. Most dryers in use today burn oil, wood or coal, although there are some all-electric units being marketed.

Photovoltaic systems would be used to power the blowers in coffee dryers, but this would be the case only if PV power were competitive with centrally generated electrical power, which is doubtful at this time.

6.1.4 Market Size Estimate

While it is possible that some of the now manually powered operations, with proper financial aid, may enter the market for some sort of power equipment, at this point this possibility is not considered likely.

Given a scenario of PV power systems being competitive with small gasoline engines, there would be a market for PV systems for use on small to average size farms that now lack electricity or an adequate electrical service (8,000 to 12,000 farms). Since there is the added benefit of PV systems to satisfy domestic electricity needs, on could envision 5-25% of the farmers buying PV systems in the 1981-86 time period.

An economic analysis showed that PV power equipment will be competitive with gasoline-engine generated power by the year 1984 in farms now using horizontal drum de-pulping machines. For farms using the less power-consuming vertical drum machines, the year of cost-competitiveness is 1982. The respective sizes of the PV arrays are 680 Wp and 480 Wp for these operations. They are capable of satisfying process power needs as well as domestic electrical needs.

The estimated market for PV equipment in this sector is about 400-2000 units of 580 Wp on the average, for a total of 200-1100 KWp for this period until 1986. The average market size may be about 300 KWp. The principal deterrent to achieving a larger market is the lack of awareness. If PV systems are favorably received, a demand for such systems is bound to continue beyond 1986.

6.2 Cattle Sector

6.2.1 Sector Characteristics

Colombia has over 41 million hectares of useful pasture for raising cattle. However beef productivity is low compared to other Latin American countries. This is attributed to poor management, low quality feed and health problems. The rate of growth for the industry is also very low.

Beef is raised on the range; there are basically three important beef-producing areas in Colombia: the Caribbean region, the Andean region and the Oriental Plains. Total beef population is estimated at 24 million head, mostly concentrated in the Caribbean (42%) and Andean (40%) regions. A small percentage of the production is exported as meat or on the hoof. Illegal exports apparently abound.

A study, Diagnostico Technologico, made by the Agricultural Institute of Columbia (ICA) points out that there exist no up-to-date or reliable statistics with regard to bovine production in Colombia and that information on the subject has to be obtained from those experienced in the industry or directly from producers and cattle associations. The team visited with several lending agencies, cattle producer association members and agricultural experts to obtain information for this study.

The Andean and Caribbean regions are the more fertile regions where cattle feed on improved pastures and some grain. Here cattle are raised at a density of 1 or 2 head per hectare. Cattle have access to natural water or water is drawn from fairly deep wells using 50-60 hp. diesel pump sets. The latter is used when electrical service is inadequate. In many cases, these same water supplies are used for crop irrigation.

The Oriental Plains, Orinoquia and Amazonia present a significantly different picture. Here the soil is not fertile and little improvement exists over natural native pastures. Natural pastures do not constitute pastures as we know them; there are simply weeds that are kept "pasture like" at an immature stage of growth by the cattle feeding and by burning.

In the Orinoquia region each head of cattle is alloted 2 to 3 hectares of land, while in some of the less fertile areas of the Amazonia up to 5 hectares have to be provided per head (land cost is a few dollars per hectare). Beef cattle in this region are taken to market after 38 months of age; the average weight at slaughter is 275 kilograms (compared to about 400 kilograms for the Andean region).

Water supplies and quality feed are major problems for cattlemen in the Oriental Flatlands.

6.2.2 Possible Uses of PV Equipment in the Beef Cattle Industry

While the more productive cattle areas are within reach of the power grid, have abundant natural water supplies or extract it from deep wells with fairly large diesel pump sets, the cattle industry in the Oriental Plains may present

a market for fairly small PV power systems. The following discussion applies to this region.

Two areas of need were pointed out enthusiastically by the General Manager and other members of Fedellanos (Cattlemen Federation of the Llanos). These two areas of need are cattle watering during dry seasons and domestic electrical needs for households. Members of Fedellanos expressed much interest in PV powered cattle watering stations since lack of water during some periods of the year is the major problem for the industry.

There are between 5 and 6 million head of cattle raised in the Orinoquia and Amazonia regions. Many agricultural specialists indicated a need for developing this region since, in their opinion, in this area lies the future of Colombian agriculture. Aside from cattle, the area presents great potential for crops such as rice, sugar cane, cotton, cassava, beans, plantains, cacao, etc., as well as fishing and fur exploitation. The area is tropical, hot and has marked rainy and dry seasons (See Table 6.2).

Cattle are raised on the range, usually 2 to 5 hectares of land per animal, depending on the region, and they are kept in groups of about 300 head. Ideally each group should have a watering station. Presently most cattle obtain their water from rivers, creeks and ponds. These dry up during December, January and February, and the little water that is available is often contaminated. During the dry season, pasture growth is also minimal. Lack of water and feed thus result in great mortality and weight loss.

Existing wells for cattle watering are minimal; the existing few have windmill driven water pumps but these are being replaced by gasoline or diesel engines. The primary reason for replacement is the low reliability of and lack of repair for windmills. Centro las Gaviotas is now manufacturing a windmill pump. The factory, located in Gaviotas, Commissary of Vichada, has a capacity to manufacture 3,000 such windmill pumps per year. Presently they have produced 4,000 units and are producing about 2,000 per year.

Gasoline and diesel powered pump sizes range from a few horsepower to 15-20 HP on the larger ranches. Gasoline as well as diesel fuel have to be transported by air in many cases, adding about 50¢ to the cost of a gallon. This results in a fuel cost of about $1.75 a gallon for diesel. Repair parts also have to be flown in to the Llanos areas, making pumping equipment operation costly.

TABLE 6.2

MEAN MONTHLY PRECIPITATION AND TEMPERATURE
FOR TWO LOCATIONS IN THE LLANOS ORIENTALES

	Station/Municipality			
	Las Gaviotas/Vichada		Santiago Peres/Arauca	
Month	Precip. mm	Temp. °C	Precip. mm	Temp. °C
January	31	26.8	9.6	27.5
February	45	27.8	9.7	28.5
March	144	27.5	30.8	29.0
April	177	26.5	93.9	27.8
May	320	25.3	153.6	26.7
June	433	24.7	241.9	26.0
July	318	24.4	282.6	25.7
August	306	24.8	192.1	26.1
September	210	25.4	266.0	26.7
October	238	25.6	88.8	27.1
November	174	26.1	106.3	27.2
December	86	26.1	20.1	27.3
Total Precipitation	2482 mm (97.7 in.)		1495.4 mm (58.9 in.)	
Average Temperature	25.9°C (79°F)		27.1°C (81°F)	

Source: Calendario Meteorologico 1981
HIMAT

Fedellanos members said that gasoline and diesel powered pumping stations are very seldom used for cattle due to operation and maintenance cost. A reliable substitute would be more than welcome by the Fedellanos members.

Beside the possibility of using PV systems for pumping water into reservoirs, Fedellanos members saw a potential for small systems to be used for domestic needs. This issue is addressed in Section 6.6. A further possibility, but perhaps more remote, would be the use of PV systems for small industries in the area dealing with furs, meat processing, fish and fruit.

6.2.3 Water Pumping Stations Characteristics

Since there are few watering stations at this time an estimate has to be made as to the future needs. Consultation with cattle ranchers indicates that ideally a watering station ought to be provided for each group of 300-400 animals. Water needs are in the order of 50-60 liters (2 cu.ft.) per head per day, or a total of 24 cubic meters (850 cu.ft.) per group per day. Reservoirs ought to be sized for a 3-5 day supply--about 100 cubic meters (3500 cu.ft.)

The water table may be as deep as 10 meters (30 ft.) Although the average is about 5 meters (15 ft.). Pumping energy required, based on 24 cubic meters and a 10 meter total dynamic head, is about 1.5 kwh/day (assuming a 50% pumping system efficiency). Mean solar radiation during the months in question for the area is 450 Ly/day, so that each individual pumping station would have to be equipped with a PV system of about 350 Wp. For this type of application it appears to make sense to use a small double-acting submersible piston pump which at a cost of $30, is already being produced in Colombia for windmill applications. This piston pump operates up to about 500 cycles per minute.

6.2.4 Market Size Estimate

An economic analysis shows that PV systems will not be cost-competitive for cattle watering until 1986. The primary reason why competitiveness is not reached until 1986 is that the PV array would not be required during six months of the year when pumping is not required. During this six-month period (May-October) rainfall provides adequate water for the cattle. However, there are many factors that would make PV watering systems desirable. These are:

- better cattle health
- less maintenance than other systems
- no need for operator travel to watering station to start up and shut off engines

- no need for fuel supply
- longevity of the system

These factors, together with the possibility of using the PV system for domestic needs during May to October, makes the proposition attractive and, in our judgement, as well as in that of the people contacted in Colombia, there would be a sizeable market prior to 1986. If above factors are considered PV systems will be competitive with other means of satisfying domestic needs as early as 1982 in areas such as the Llanos Oriental where fuel costs are high.

Data from Caja Agraria (Table 6.3) indicate that about 200 pump sets were sold last year in the area. Assuming a competitive price, one may expect PV sales in the year of cost-competitiveness to be about 10% of such figure, perhaps increasing at a rate of 25 per year. This estimate reflects the opinion of the cattle federation officials. Under these conditions the market for the 1981-86 timeframe would be about 102 KWp (300 sets of 340 Wp). Under more optimistic circumstances a market for about 500 sets could develop during 1981-86.

6.3 Rural Water Supplies and Small Irrigation

6.3.1 Sector Characteristics

According to some of the contacts made in Colombia there would be an extensive market for PV powered pump sets to satisfy domestic water needs and small irrigation needs for rural families. As the team researched the subject, it became evident that while the need for water exists, the market for PV equipment for this use is hard to estimate.

According to Incomex, Barnes de Colombia and Caja de Credito Agraria, about 5,000 pump sets are being sold yearly in Colombia, the vast majority being small 3-5 HP gasoline sets. To a great extent these are used as standby equipment due to the unreliability of centrally generated power and for applications where the portability of this equipment is important. In many cases, gasoline powered pump sets are purchased solely for convenience rather than need.

Since most of the population is centered around the Andean region, where natural water supplies and electricity are available, the need for communal water supplies is slight. Those without piped water into their houses obtain it from community water sources (shallow wells, aqueducts, reservoirs, creeks, etc.). This group of people cannot afford any other means for obtaining their water.

TABLE 6.3

SALES OF GASOLINE POWERED PUMPS AT THE ORIENTAL AND VALLEDUPAR OUTLET OF CAJA DE CREDITO AGRARIA (1980)

Type	Size	Price	No. Sold
Make/model	HP /dish. diam.	U.S. $	
Barnes/5ccg	3 HP/1½ in.	$ 412	34
Barnes/7ccg	3 HP/2 in.	$ 414	39
Barnes/9ccg	5 HP/2 in.	$ 482	20
Barnes/18ccg	7 HP/3 in.	$ 888	7
Barnes/12ccg	3 HP/1½ in.	$ 484	9
Barnes/2015 HC	7 HP/2 in.	$ 844	6
Barnes/2020 HC	9 HP/3 in.	$1188	1
1 HM/5G-6	2 HP/1.5 in.	$ 313	5
1 HM/8G-8	3 HP/2 in.	$ 351	13
1 HM/5G-8	3 HP/1.5 in.	$ 349	4
1 HM/5n	2 HP/1.5 in	$ 299	13
1 HM/5n-8	3 HP/1.5 in.	$ 332	7
1 HM/7M	3 HP/2 in.	$ 335	30
1 HM/17 M	7 HP/3 in.	$ 831	6
			194

Families in the less populated areas of the Oriental Plains obtain their water from creeks or shallow wells. Apparently water supplies here are not the central issue; the problem many times is water quality, since sanitary facilities are lacking.

For those cases where water supply is solely dependent on gasoline powered pump sets, data showing amounts of water needed or hours of operation of the pumping equipment is not available. Based on conversations with pump distributors, agricultural experts and producers, one could deduce that these sets (average 3 HP) are used one-half to one hour per day, year around, and pump water into reservoirs, or large tanks. This being the case, these systems require 1 to 2 kwh per day.

The cost of a gasoline powered pump set of the type described above is about US$420 with operation and maintenance cost of US$250/year. The present value of such a system operated for 20 years then equals about US$3,000. Under this condition, a PV powered pump set (500 Wp) would be competitive with gasoline powered equipment prior to 1984.

6.3.2 Market Size Estimate

Assuming that 10% of the pump sets sold operate in conditions similar to those described here, a market as large as 250 KWp would exist for PV powered water pump sets in any one year.

The question of how many buyers of water pumping equipment would consider buying PV systems at considerably higher initial cost but competitive life cycle costs cannot be answered definitively. Given the conditions and many conveniences of PV equipment, one would conjecture a market size for 300-500 sets totalling about 200 KWp to exist for the early 1980s based on the subjective judgement interviewees.

6.4 Rural Telephones

6.4.1 Sector Characteristics

The only significant PV activity presently going on in Colombia has to do with PV powered rural telephones (See Section 2.3). The Colombian Telecommunication Authority, in Phase I of its rural telephone program, has contracted for the installation of 2,000 PV powered telephore units. This contract was granted to Lucas Energy Systems of England.

Phase II of the program, solicitations for which will be released late in 1982, calls for 2,200 PV powered pay phones to be installed. The complete program seeks to provide telephones to every locality with a population exceeding 200 inhabitants. The second phase of the Rural Telephone program has five objectives, to be carried out between 1982 and 1986:

1. complete services to all communities larger than 200 inhabitants
2. study and satisfy private communication needs
3. study and satisfy mobile communication needs
4. provide telephones to the Llanos Orientales (250 communities)
5. evaluate phases I and II of the program

The needs to satisfy objective 1 have been established (2,200 pay telephone units) while objectives 2-4 are undergoing feasibility studies.

6.4.2 Market Size Estimate

The immediate market size for PV systems called for in phase II of Telecom's program consists of 2,200 systems, average size 72 Wp for a total of 160 KWp.

It has also been estimated that an immediate market for private communication exists for about 125 similarly sized units. Thus, the total rural communication market in the 1981-86 time frame is about 170 KWp.

6.5 Rural Health Posts and Health Centers

6.5.1 Sector Characteristics

According to health authorities in the National Planning Department and Ministry of Health, the health problems in Colombia are in rural areas due to the inability of medical personnel to reach and provide vaccinations to people in rural, isolated regions.

Expenditures in health programs have increased considerably in the last 10 years and account for almost 10% of the national budget. From 1978 to 1979 appropriations for health programs increased 22% reaching $221 million. From administering vaccinations) has doubled, but it is estimated that they only cover 35% of the needs.

Health care in rural areas is conducted at health posts and health centers and hospitals. There are about 850 hospitals in Colombia, 544 health centers and 1,500 health posts.

Health centers usually have a permanent doctor and have facilities for minor surgery, and many have 5-10 beds. They usually require a year-round supply of electricity and are tied to the electric grid. They may have stand-by engine generator sets in the range of 5-12 KW.

Health posts are attended by a nurse or nurse's aid and may have a doctor occasionally. In isolated areas posts may have engine generator sets in the range of 1.5-3.0 KW and are used only 3½ hours/day. Refrigerators are kerosene powered.

There are about 3,000 rural health promoters; each covers an area of about 3 square miles. They travel on horseback or bicycles, obtaining their vaccines from health posts or centers. Vaccines are kept refrigerated in thermos bottles. In 1979, they administered 1,323,939 TB vaccines, 418,302 polio vaccines, 744,834 measle vaccines and 393,622 DPT vaccines.

6.5.2 Potential for PV Applications

There are three main areas where PV systems would be applicable in the rural health area:

- power systems for health posts;
- health post refrigeration and
- small refrigerators for vaccines used by health promoters.

Power systems for health posts would be sized in the range of 1.5-3.0 KWp with storage capacity for 3 days. (This assumes an energy consumption of 6-8 kwh/day and that use would be limited to absolute necessities during cloudy periods).

The market for these systems would probably be limited to new installations or to those where generators are being replaced. Funds for the purchase of such equipment would have to come from the Colombian government or a national or international health organization. There is a drawback to the use of PV systems on some rural health posts in that power is needed in a fairly erratic schedule, as when emergencies occur, and under those conditions there is a tendency to favor gasoline powered equipment.

Refrigeration in health posts is now provided with kerosene powered units with about 10 cubic feet capacity. Most of these units are Electrolux and cost 45,000 Colombian pesos (US$1,000).

Kerosene consumption for these refrigerators is about one liter per day at a cost of roughly 15 cents per day.

Assuming a similar sized electrical refrigerator, it would consume about 1.5 kwh/day. A simple comparison of these costs would indicate that PV powered refrigerator could not compete with what is presently being used due to cost. (NOTE: The NASA team conducting a similar study in Mexico arrived at the same conclusion in that country, DOE/NASA-0180-4).

TABLE 6.4

MARKET SIZE ESTIMATE SUMMARY

APPLICATION	ARRAY SIZE KWp	NUMBER	TOTAL KWp	FIRST YEAR OF COST-COMPETITIVENESS
1) Coffee de-pulping				
horizontal drum + domestic use	0.68	100-500	68-340	1984
vertical drum + domestic use	0.48	500-1500	240-720	1981-82
2) Cattle Watering & other needs	0.34	300-500	102-170	1982
3) Rural Domestic	1.15	400-700	460-805	1982-84
4) Rural Water Supply	0.5	300-500	150-250	1983-84
5) Rural Telephone	0.072	2200-2325	158-168	1982
6) Rural Health Posts	1.75	40-50	70-90	1983
7) Vaccine Refrigeration	0.100	30-50	3-5	1982
		TOTALS	1254-2553	

Small refrigerator-freezers for vaccines of the cold-chain type (polio, measles, etc.) may be a potential application for PV systems. Presently thermos-type containers are carried by health promoters in their vaccination campaigns. These containers can maintain proper temperatures for up to two days, but there are many regions in the country that cannot be reached in that time. Life expectancy in those areas may be as little as 35 years. The social and economic benefits of having PV powered refrigeration for this purpose are hard to estimate. Since no practical alternative is available, PV powered refrigerator-freezers will become feasible as soon as their usefulness is successfully demonstrated. Thus, they could become technically and economically feasible by 1982.

6.5.3 Market Size Estimate

Economic analysis indicated that PV systems to provide electricity for rural health posts will be competitive with gasoline powered systems as early as 1983 depending on location and fuel costs. The market size for PV systems would probably be limited to new installations and those being replaced, this number is estimated at 5-7 per year for the 1980's; this would limit the market to about 40-50 PV units. The total 1981-86 market would be about 60-75 KWp.

The Health Division of the National Planning Department, estimates that as many as one thousand vaccine refrigerators could be used by health promoters. Realistically speaking, one would expect that, with proper lobbying and financing, a market for perhaps 10 units a year would exist for the 1981-86 timeframe. The total market for PV systems in rural health applications would be about 70-90 KWp in the 1981-86 timeframe.

6.6 Rural Domestic Uses

6.6.1 Sector Characteristics

Time and time again the need for basic electrical service to rural families was pointed out by contacts in Colombia. Using PV systems to satisfy basic electrical needs in rural areas was of great interest to most of the contacts.

Statistics[1] show that only 57% of potential subscribers have electrical service now. This amounts to 2.11 million users or 14.2 million inhabitants. Left without electrical service are some 10.8 million people (1.6 million families). It is also estimated that 86% of the urban population has electrical service while only 13% of the rural sector is connected to the electric grid. By demographic zones then, there are 522,000 urban families and 1,113,000 rural families without electrical service.

6.6.2 Potential for PV Applications

As discussed in Chapter 2, despite the intensive electrification program, a large number of rural inhabitants will not have electrical services in the late 1980s. Herein lies some potential for PV equipment. The type of users in this category fall into four classes:

- Wealthy ranchers and land owners who need power on their estates when they visit them. They presently have small diesel or gasoline powered generator sets. There are about 4,000 generator sets (averaging 3 KW) imported to Colombia every year. As many as 5% may be going to these wealthy landowners. Statistics are not available to determine where these sets go, or how many hours a year these are used. Many of these landowners are absentee landowners who may visit their ranches 20 or 30 days a year. Based on conversations with cattle ranchers, importers, agricultural experts and electric company personnel, the market for PV systems would be about 20-40, 1.0-2.0 KWp PV systems per year, starting immediately, if they were almost competitive with small generator sets. Apparently PV systems would not have to be strictly competitive with gasoline systems on a cost basis; people would buy them at a premium price due to convenience (e.g., no need to transport fuel).

- The second class of non-electrified user that may consider a PV system for domestic uses would be those who require electricity but simply are not close enough to the power grid for this to be economically possible. Unlike the previous group, these users require power year-round. These would be the 16,000 landowners who own land in the range of 200-1,000 hectares. A conservative estimate would be that 0.5% of this group might buy PV systems if they were competitive with gasoline powered generators in the 1-3 KW range.

- A third potential PV system user would be those communities of less than 200 people not served by or included in the rural electrification plans. The needs of these small communities would include a central water pumping station, community center (e.g., communal TV, refrigerator, etc.) and perhaps some very small industry. While authorities in DRI/DND (Integrated Rural Development/National Planning Department) saw this as a "nice" possibility, prospects for such installation materializing are minimal, mainly due to lack of financial resources.

- A fourth and last possibility for using PV systems to satisfy rural domestic electrical needs would be small individual family system for basic lighting and radio use. If any power system were to compete with other sources of energy for domestic uses, the sources of energy replaced would be wood and coal for cooking and dry cells for lighting and powering radios.

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1 Plan de Integracion Nacional-Departments Nacional de Planeacion, 1980.

A study conducted for the Integrated Rural Development (DRI) program in 1977 shows that the average rural family spent 8,000 Colombian pesos (in 1977 about US$250) per year in such forms of energy.

On a weekly basis this study shows each non-electrified rural family using 150 kilogram of firewood, 75 kilograms of coal, 2 gallons of kerosene, 12 candles and one 6 volt dry cell. The energy content of these sources amounts to 1,500 kwh/week of which about 100 Kwh/week goes to lighting and powering radios. The cost of kerosene, candles and dry cells was estimated at 160 Colombian pesos (1977) per week (US$5) per family.[1] Since the efficiency of conversion to light of the above mentioned fuels is so low, it is estimated that the 100kwh of kerosene, etc., are equivalent to only 20 watt hours of electricity. (For example, one mantle type kerosene lantern burns one liter of kerosene in about 6 hours, the equivalent of 1.2 KW, to produce lighting similar to a 200 watt bulb.) Under these conditions, the typical Colombian non-electrified rural resident pays the equivalent of 25 to 30¢ per kwh for his lighting needs. Unfortunately, few if any rural families have access to $2500 or $3000 to acquire a small PV system (income less than US$200 per year). The only possibility in this area would be for those families involved in the production of established, marketable produce such as coffee, which may count on the help of programs such as Prodesarroll (See Section 6.1).

6.6.3 Market Size Estimate

Providing PV systems become cost competitive with small (about 2,000) watt gasoline powered generator sets, and meet conditions as described above, a market for 1-2 KWp systems would exist for rural domestic uses for the large and medium size landowners.

An economic analysis showed that PV systems would be competitive with gasoline powered generators as early as 1982, depending on fuel costs. (See summary table.) A market for as many as 600 1.15 KWp systems may exist through 1986 for a total of 690 KWp in this area.

The total market for PV systems in rural health applications would be on the order of 70-90 KWp in the 1981-86 timeframe.

6.7 Summary of Applications Showing Significant Market for PV Systems by 1986

Table 6.4 is a summary of potential uses for PV power systems that were found to present a significant market. The table shows respective array sizes, potential number of applications, market size and year of cost competitiveness.

1 Energia Rural (Rural Energy) Informe del Grupo de Energia en Areas DRI Bogota, Dec. 1977.

The market size estimates are presented as ranges, the lower figure being representative of a market development under conditions of little extra government support and financing over what exists now. Also, these lower figures reflect the fact that the timeframe of this study is only 3 to 4 years to develop a market for PV systems. This amount of time is very short, particularly given the financial and social conditions of the country.

The higher figure assumes aggressive marketing by the PV companies, assisted by financial as well as educational and awareness campaigns, possibly with the backing of the Colombian government.

7.0 APPLICATIONS SHOWING LITTLE PROMISE FOR PV SYSTEMS

The following applications were evaluated and were found to have little technical and economic feasibility. The primary reasons for the inappropriateness of stand-alone PV systems is large power requirements, no year-round energy demand or because plants are located near the grid.

7.1 Brown Sugar (Panela) Production

7.1.1 Sector Characteristics

Brown sugar is produced from sugar cane by small land owners in Colombia throughout the temperate and warm regions. The total land devoted to this crop is about 300,000 hectares generally in the North Western half of the country. Sugar cane for brown sugar is planted in the same regions as coffee. The labor force is shared between the two crops and fluctuates from one to the other depending on the price for each.

It is estimated that as many as 300,000 families derive part of their income from the production of brown sugar. There are approximately 63,000 trapiches (cane milling and processing plants) which process 9.3 million tons of cane resulting in almost 1 million tons of brown sugar per year.

Cane is harvested throughout the year. When a large enough batch has been harvested (about 5 tons) it is put through the milling and cooking process. The cane is crushed and the juices are collected and cooked until the consistency of the mash is thick enough to be put in molds. Once the sugar is crystallized, it is crushed.

The crushers are driven mostly by mules or diesel engines, although there are a few powered by electric motors and water wheels. Engines are primarily Lister, ranging from 8 to 24HP, the most common being the smaller size. It is estimated that only about 25% of the trapiches are mechanized.

Energy for cooking the juices is derived from the bagasse, wood, coal and even old tires.

7.1.2 Market for PV Power Systems

There is little if any possibility for PV systems to be used in the Panela industry. The reason is the large size of the power plants needed and the very few hours a year that they are operated. The typical crusher is used only an average of 150 hours per year; and when it is operated, it is required to work for several hours at a time. A PV system designed for such operations would necessarily have a very large storage capacity. This would make the system very expensive and the advantage of a declining cost in solar cells in years to

come would not result in as pronounced a decline in the total system installation and operating cost. There may be a small market for PV systems for domestic electricity uses for farms producing brown sugar, as was discussed in Chapter 6.

7.2 Cassava (or Yucca)

Four percent of the planted cropland in Colombia is devoted to cassava. Production in 1980 reached 2.7 million tons; acreage involved in growing the crop is about 250 thousand hectares. Cassava is often grown in rotation with other staples and it is consumed mostly where grown. Eighty percent of the production is consumed fresh, about 18% is fed to animals (hogs, poultry and cattle), the rest is used for starch production.

Cassava grows throughout Colombia, from sea level to 2,000 meters in altitude. The larger producers are the departments of Antioquia, Bolivia, Santander, Cordoba, Cesar, Meta and Cauca.

Cassava is largely grown by small producers, it does not keep well and therefore very little large scale commercial production takes place. It is estimated that there are about 160 central processing plants in Colombia with a capacity to process 1,000-2,000 Kg/day. Processing cassava into starch involves a washing process, grating and fermentation, followed by straining. Processing plants typically use 5 HP motors, one for washing, one for grating and one for straining.

An effort is being made by Centro las Gaviotas to market a small, bicycle type grating machine for the small producer. This human powered machine has a 120 kg/hr capacity, and while it would help to preserve cassava in a certain way (like bread or starch), Colombian agricultural experts see little future in the use of such machines.

The little cassava that is processed, is processed in centrally located plants which are fed by the electrical power grid. Much the same is true for many other agricultural commodities in Colombia. Cassava production does not offer any significant market in terms of PV equipment applications.

7.3 Fique

Fique (sisal-like fiber) manufacture was investigated as a possible PV application in decentralized regions since it is a crop for which some of the processing is done at the farm level.

About 32,000 hectares are devoted to this crop; the productivity is about 1,500 kg per hectare. Fique is grown mostly in Cauca, Santander, Antioquia and Norte de Santander.

Fique is harvested, the leaves are crushed and the fibers extracted, then put through a fermentation process and finally dried. The dried fibers are then taken to central mills for the manufacture of tieing, wrapping and packing items.

There are an estimated 5,000 stripping machines used at the farm level. These are used to obtain the fiber from the leaves. They use 5 to 7 HP gasoline engines.

Fique processing does not appear to be a feasible PV application area since the engines used at the farm level receive a small amount of yearly use and as in the brown sugar making process, when they are used, the demand is very high. This would require extensive energy storage capacity and the cost would be prohibitive. Further, packing manufacturers repair and maintain these engines at little cost to the farmer to assure themselves of a steady supply of fiber.

Processing of the fiber beyond the farm level is done at large plants which derive their energy needs from the power grid.

7.4 Sugar Cane

Sugar cane is an important crop for Colombia's domestic consumption as well as export. Almost 140,000 ha are devoted to this crop yielding 1,134,400 tons of sugar. While cane grows throughout the country the major sugar cane growing region is in the Cauca Valley where there are 16 large sugar mills. All sugar is processed in large mills many of which have control over extensive land areas or have contracts with producers for their crops.

A new stand of cane is planted every 10 years and harvested every 14 months. Plantings are scheduled so that harvesting is continuous through the year. Cane is cut by hand and placed on piles from which a grate-type loader loads it into trucks or wagons to be taken to the mills.

Sugar cane has to be irrigated about 8 to 10 times in the 14 month production cycle. About 2,000 to 2,500 cubic meters of water are used per hectare per cycle. Irrigation is done mostly by furrow although sprinklers are used.

Irrigation water is extracted from deep wells. In the Cauca Valley distance between wells and well depths are regulated by CVC (Corporacion Autonoura Regional Del Cauca). Wells are not closer than 1,000 meters from each other and the depth has to be 130 m. Water pumping is done with turbine type pumps, mostly Worthington or Berkeley, driven by 100-110 HP engines (Detroit, J. Deere, Fiat)

Energy uses in the sugar cane area are restricted to land preparation, harvesting, irrigation and milling. Their requirements are satisfied by equipment much larger than the PV systems considered in this study or, in the case of processing, by equipment powered by the electric grid. Other than domestic uses for families involved in cane production the sugar industry does not present a market for PV systems.

7.5 Rice

Eight percent of the available land in Colombia is devoted to rice; most of which is consumed within the country. While rice is produced just about everywhere in Colombia the departments of Tolima, Meta, Huila, Cesar and Sucre produce 75% of the total. It is estimated that almost 80% of rice production is fully mechanized. There are two harvests per year.

Cropping practices are split equally between paddy and dry cultivation, but irrigated rice fields produce almost 2½ times as much as dry cultures. Rice production and yields have increased considerably in the last 20 years through the efforts of Fedearroz, CIAT and HIMAT by developing new varieties and extensive irrigation projects.

Irrigation is done in a fairly large scale using 100 hp and greater diesel pump sets with turbine type deep well pumps. Irrigation water needs are about 14,000 m^3/ha/year.

Once harvested, rice has to be dried from 22 to 13 percent moisture, this is done in centralized locations on large silos utilizing fuel oil burners with 50 hp blowers.

There is an effort being make to have small producers dry their own rice to avoid spoilage. S.B. Industrial & Commercial Company is presently offering some small driers, similar to those used for coffee, but sales have been minimal.

Rice production in Colombia does not appear to offer much of a market for PV systems. Drying and milling are done in large centralized mills whose power requirements are many times those that could be provided by PV systems considered in the study. Irrigation too, is done on a very large scale. Thus, the use of PV systems would be limited to the very small producer. The small producer, at this time and most likely for some time to come, will either risk a loss or rent equipment for drying his crop as well as for irrigation.

7.6 Cotton

Cotton is an important crop in Colombia. There are approximately 200,000 ha planted for the production of oil and fiber. Cotton producing areas are concentrated on the northern coast and down along the Magdalena river (departments of Cesar, Magdalena, Atlantico, Bolivar, Sucre and Cordoba) and in the interior around Cauca River (Valle, Cauca, Tolima, Huila, Cundinamarca and Caldas).

Cotton production is mechanized, following cultural practices as in the Mississippi area of the U.S. Approximately 30% of production is mechanically harvested while the rest is harvested by migrants. Much of the crop is irrigated. About 10-15 inches of irrigation water on the average is needed. However, water requirements vary widely from year to year. Cotton is processed in 40 central processing plants located throughout the growing regions. There is no processing of cotton or drying at the farm level.

Cotton production does not present a market for PV applications. Cotton is grown in well electrified areas, irrigation is done using 100 hp diesel pump sets and all processing is done in fairly large central plants.

7.7 Corn

Corn is planted throughout the country in very small units. 97% of the production comes from plots less than 5 hectares. Most producers have arrangements to sell the ear corn to feed mills such as Corabastos. Some of the production remains at the farm for the family's use. This is shelled and ground by hand or in small mills. There is very little mechanized corn milling at the farm level although there are gasoline or electric powered mills available. Many of these are brought by custom operators that travel from farm to farm.

Corn production was estimated in 1980 at 812,800 tons from an area of 624,500 hectares.

Corn production does not offer a market for PV power equipment; this is mainly because of the rudimentary techniques used and the very small quantities which are grown, mostly by families of little means.

Corn which is milled for human consumption and feed manufacture is processed on large mills which obtain their power from the electric grid.

7.8 Flowers

Flowers represent one important and growing source of export revenue for Colombia. There are now 60 large firms dedicated to this activity which employs about 400,000 workers.

Due to their irrigation, lighting, processing and refrigeration needs, flower producers are located in areas served by the power grid. There is little if any, future for PV application in the flower industry. One contact, from Flores del Cielo Ltd., felt that there may be an application for small PV systems to operate electronic controls for lighting and ventilation, or perhaps alarms. but felt that such market would be minimal and it would be "stretching things."

7.9 Small Grains and Oilseeds (wheat, oats, barely, sorghum, sesame, soybeans)

Small grains are planted in Colombia mostly in the colder regions of the central highlands (Boyaca, Antioquia, Santander).

Oilseeds, particularly sesame, are produced mostly in the Tolima area (80%), the rest being produced sparsely in some of the Northern departments.

Drying of the seeds, when necessary, is done on the fields. The produce is then taken to central mills and processing plants. Neither small grains nor oilseed present a market for PV equipment due to the nature of the cropping practices and the centralized large scale processing.

7.10 Dairy

The population of dairy animals in Colombia was estimated in 1980 to be about 3.8 million head. Milk production averages 1,175 kg/head/yr. Over 80% of the dairy cattle in Colombia are kept in the well electrified Andean regions, notably in the areas surrounding Bogota. Most dairies are small in size, 40 head or less, and are not mechanized. Most of the milk is not refrigerated at the farm level. The market for PV power in the dairy industry is severely limited since the larger producers, those which would utilize mechanized equipment are established where road systems and electrification are well developed. Milk producers are actually threatened by expanding urban development since they are mostly in well-developed areas of the country.

7.11 Poultry

The poultry industry in Colombia presents, as far as PV applications are concerned, a similar situation as does dairying. It is located close to large urban developments and expansion only occurs in electrified areas.

The poultry industry, both egg and meat production, has grown significantly in the last few years. Broiler production is expected to increase at a rate close to 10% per year in the early 1980's, while ASOHVEVO (Egg Producer's Association) estimates a 5% increase in layers this year.

New egg production units house hens in cages. Some are complexes of four to five buildings housing over 20,000 birds each. Electrical requirements

for these farms are few (lighting, water supply, feed conveyance and ventilation) and these are always met by centrally generated electricity.

8.0 CONCLUSIONS

Colombia presents a promising market for photovoltaic equipment. Over twenty applications of PV systems were investigated during the field visit. Several applications, requiring less than 5KW of power, present a significant market potential in the 1981-86 timeframe. As determined by the team, the market for PV power systems in Colombia for the years 1981-86 lies in the range of 1200 to 2500KWp. Due to current status of government and private sector activities and attitudes the most probable effective market size will be close to the lower figure. Table 8.1 gives the summary of the market. Factors positively influencing the PV market are summarized below:

- Lack of electrical services. Less than 60% of potential users are now being served by the electrical utility companies--there are an estimated 1.6 million families without electricity.

- Electrical generation plans behind schedule. While there exist extensive plans for the exploitation of hydroelectric power, these plans are not expected to meet demand for many years. Blackouts, planned or otherwise, occur about every day. Alternatives are being sought.

- Llanos Orientales Development. The vast Llanos Orientales Territory lacks electrical power and estimates are that this area will continue to be unelectrified. There is a great potential for agricultural and small industry development in this area and this would require power.

- Cost of fuel in remote regions. While fuel is relatively inexpensive in developed areas, it may cost 2 to 3 times as much in remote regions due to transportation costs. PV systems would be competitive in the early 1980's with presently used gasoline or diesel generators.

- Balance of system availability. Colombia is fairly industrialized; there are at least 18 large companies making automobile batteries and many more manufacturing electrical equipment. Deep discharge batteries are not presently manufactured, but given the market, the industry may tool-up easily. Expertise in electricity and electronics is abundant; installation and maintenance of PV powered systems would not be a problem.

- Wealthy Land Owners. While the per capita income in Colombia is low on the average, there are many very wealthy land owners who could afford PV systems to replace presently used generator sets or other equipment for cattle watering, domestic electrical users, small irrigation etc.

On the negative side one also finds important factors with regard to PV applications. They are summarized below:

- Relatively inexpensive energy in most locations. In the highly developed Andean region prices for gasoline and diesel fuel are below a dollar a gallon, and prices for electricity range from 3 to 7 cents/kwh.

TABLE 8.1

MARKET SIZE ESTIMATE FOR PV POWER SYSTEMS IN COLOMBIA, YEARS 1981-86

APPLICATION	FIRST YEAR OF COST COMPETITIVENESS	MARKET SIZE RANGE KWp
Coffee Sector	1982-84	308 - 1060
Livestock	1982	102 - 170
Rural Electricity Uses	1982 - 84	460 - 805
Rural Water Supply Small Irrigation	1983 - 84	150 - 250
Rural Telephones	1982	158 - 168
Rural Health Posts	1983	73 - 95
Vaccine Refrigeration	1983	3 - 5
		1251-2553

- Reliance on Hydropower. Colombia has a great potential (about 20 times the existing capacity) for hydroelectric power generation. Justifiably many contacts felt that PV systems may have little application if present development plans are carried through.

- Lack of Familiarity with PV equipment. The majority of contacts made confused PV cells with solar thermal panels. Farmers and others involved in agriculture had no knowledge of such systems. Research and development in the area is non-existent for all practical purposes.

- Lack of financing. The longest term financing available is 6 years for agricultural equipment; and interest rates are high. While a life cycle cost analysis may show cost-competitiveness for PV equipment, it may be out of each for many users due to high initial cost.

One significant drawback in the conduct of the study was the lack of documentation with regard to energy usage and load profiles for energy-requiring activities. There are efforts being made currently by the U.S. Embassy personnel, ICA and other institutions to document energy requirements, in agricultural as well as other activities, but little data is available currently. In making a market assessment for PV equipment one has to rely on verbal communication with "experts in the fields" or specific information gathered during field visits which may not be truly representative of a particular industry.

APPENDIX A

LIST OF CONTRACTS

FINANCIAL INSTITUTIONS

Banco Ganadero — Cattlemen's Bank
Carrera 5, No 15-80, Piso 2
Bogotá
Tel 284-8219

- Dr. Jose Alejandro Pizzarro, Director, Agriculture Credit Division
- Sr. Jorge Tovar, Officer, Agriculture Credit Division

Caja de Credito Agraria, Industrial y Minero — Agricultural, Industrial and Mining Credit Bank
Carrera 8, No 15-43
Bogotá
Tel 284-4600

- Dr. Victor Duran, Director, Economic Studies
- Sr. Alberto Romero-Martinez, Chief Economic Studies Division
- Sr. Alfonso Piliti-Mendoza, Chief, Market Investigation Division
- Dra. Carmen Alicia Neira, Assistant to Subdirector for Planning

Fondo Financiero Agropecuario — Agricultural Financial Fund of the Bank of the Republic
Edificio Avianca, Piso 36
Bogotá

- Sr. Javier Ramirez, Statistics Section

FEDERATIONS

Federación de Algodoneros — Cotton Growers' Federation
Carrera 8, No 15-73
Bogotá
Tel 284-7618

- Dr. Jairo Cadena-Rivera, Director, Technical Division

Federación Nacional de Arrozeros [FEDEARROZ] — National Federation of Rice Growers of Colombia
Calle 72, No 13-23, Piso 9
Bogotá
Tel 255-5911

- Dr. Nestor I. Rodriguez-Medina, Chief Technical Assistance Department

Federación Nacional de Cafeteros de Colombia — National Coffee Growers' Federation of Colombia
Calle 14, No 7-36, Piso 6
Bogotá
Tel 242-9994

- Dr. Gilberto Robledo-Robledo, Subdirector, Development and Diversification Program
- Dr. German Valenzuela-Samper, Technical Director
- Ing. Jaime Nades, Engineering Division

FEDERATIONS

Federación de Ganaderos del Llanos (FEDELLANOS)
Calle 65, No 13-50, Piso 5
Bogotá
Tel 255-7445

Cattlemen's Federation of the Llanos*

- Dr. Arturo Mejia-Borda, Manager
- Sr. Jairo A. Majia-Sarimento, Member
- Sr. Luis Fernando Tobian, Member

*The Llanos is a river situated at 5.00 N, 70.00W

RESEARCH CENTERS

Centro de Investigación de Agrilcultura Tropical
Recta Cali—Palmira, Km 167
Apartado Aereo 67-13
Cali
Tel 680-111

Tropical Agriculture Research Center

- Sr. Fernando Mora, Information Officer
- Sr. Rodrigo Chaves, Crop Specialist
- Sr. Jorge Enrique Paz, Crop Specialist
- Ing. German Gutierrez, Maintenance Engineer

Centro de Investigación de la Caña
Avenida 3a Norte, No 44N-36, Piso 3
Cali
Tel 687-926

Sugar Cane Research Center

- Ing. Manuel Grillo, Irrigation and Drainage Specialist

Centro de Investigación del Cafe
Chinchiná,* Caldas**

Coffee Research Center

- Ing. Jaivo Alvarez Hernandez, Agricultural Engineering Section
- Dr. Oscar Cardona Alvarez, Administrative Director
- Dr. Alfonso Uribe Enau, Chief, Department of Agronomy and Technology

*Chinchiná is a town situated at 4.58 N, 75.36 W

**Caldas is a district between coordinates 5.15N, 75.30 W and 6.05N, 75.38W

EDUCATIONAL AND SCIENTIFIC INSTITUTIONS

Instituto Colombiano Agropecuario — Colombian Institute for Agriculture
Calle 37, No 8-43, Piso 8
Bogotá
Tel 232-4693

- Dr. Jaime Navas Alvarado, Research Manager
- Dr. Pablo Buritica, Chief, Agronomy Research

Instituto Colombiano Agropecuario
Tibailata Research Center

- Ing. Fernando Moreno Pinzon, Agriculture Processes Division
- Ing. Reinaldo Pinto S., Agriculture Processes Specialist

Instituto Colombiano de Comercio Exterior (INCOMEX) — Colombian Institute for Foreign Commerce
Calle 28, No 12A-15
Bogotá

- Sr. Jose Antonio Balle, Chief, Statistics Section
- Sr. Luis Yacit Hoyos, Agriculture Section

Instituto Colombiano de Energia Electrica (ICEL) — Colombian Institute for Electrical Energy
Carrera 13, No 27-00, Piso 4
Bogotá
Tel 241-7841

- Ing. Eutimio Becerra Reyes, Chief Alternate Energy Division
- Ing. Victor Borrero
- Dr. Jose Pedraza, Rural Electrification Division
- Ing. Elsa Lucia Deaza, Rural Electrification Division

Instituto de Asuntos Nucleares — Institute for Nuclear Issues
Avenida El Dorado
Apartado Aereo 8595
Bogotá
Tel 268-0600

- Dr. Clemente Garavito B., Director, Solar Energy Projects
  President, Geographic Society of Colombia

RURAL DEVELOPMENT

Desarrollo Rural Integrado (DRI) — Integrated Rural Development
Carrera 10, No 27-00, Piso 11
Bogotá
Tel 282-4055

- Dr. Carlos Sarmiento, Rural Electrification Planning

Centro las Gaviotas
Paseo Bolivar, No 20-90
Bogota
Tel 241-9967

- Dr. Paolo Lugazi, Director General
- Dr. Jorge Zapp, Technical Director
- Dr. Sven Magnus Zethelius, M.D.

PRIVATE-SECTOR ENTREPRENEURS AND ENTITIES

Flores del Cielo — Sky Flowers, Limited
Carrera 10, No 28-49
Bogotá
Tel 243-0414

- Ing. Moises Kestenberg H.

Irrigaciónes Limitada — Irrigations, Limited
Calle 12, No 33-09
Bogotá

- Sr. Jaime Escobar, Partner

S. B. Industrial and Commercial
Carrera 40b, No 9-31
Bogotá
Tel 247-1308

- Sr. I. H. S. Bridger, General Manager (Grain-Drying Equipment Manufacturer)

Technibombas
Madrid, Cundinamarca

- Sr. Joseph Napoleon Moreno

PORT AUTHORITY

COLPUERTOS — Colombian Port Authority
Bogota
Tel 234-3701

Sr. Alberto Rodriguez

C 2

APPENDIX B

DOING BUSINESS IN COLOMBIA

B.1 Introduction

This appendix examines the distinctive features of doing business in Colombia. Section B.2 provides information on general Colombian business practices relevant to U.S. businessmen. Regulations and procedures regarding the importation of U.S. goods into Colombia are treated in Section B.3. Section B.4 treats laws governing foreign investment in Colombia, with special emphasis on the Andean Foreign Investment Code. Finally, Section B.5 details the various forms of business enterprise which exist in Colombia.

B.2 Colombian Business Practices

A major adjustment for Americans doing business in Colombia and elsewhere in Latin America is the difference in perception of time. In general, Colombians do not have as rigid a sense of time as Americans. Therefore, it is wise for Americans to adopt as flexible an attitude towards time as possible while retaining the degree of cordiality and professionalism customary in Colombian business transactions. Personal relations are also very important in doing business in Colombia. Colombians often like to develop a good rapport with business contacts before conducting business transactions. Personal references and contacts can be very helpful in gaining access to government officials and business managers. Appointments should be arranged in advance; it is inadvisable to arrive at an office unannounced and expect to be given an appointment promptly.

Although Spanish is the official language, many Colombian businessmen and government officials speak English, often as the result of American university training. However, many do not feel comfortable speaking English in business situations, so it is highly recommended that American firms send personnel to Colombia with a good command of Spanish. Similarly, materials such as catalogues and pamphlets should be printed in Spanish if possible. Finally, it is a good idea to bring along an ample supply of business cards to exchange at meetings.

Colombian business contacts should be addressed by their titles unless they are personal friends. Some of the most commonly used titles are Licenciado(a) - person with a bachelor's degree, Ingeniero(a) -

person with an engineering degree and Arquitecto(a) - person with an architecture degree. Doctor, or Doctora is used not only to refer to persons with doctorate degrees, but also designates respect or authority.

Colombian time coincides with U.S. Eastern Standard time. In general, office hours run from 8:00 a.m. to 12:00 p.m. and from 2:00 p.m. to 5:30 or 6:00. Government offices prefer to do business with the public after 9 a.m. Some offices are open Saturday mornings, but generally a five-day work week is observed.

B.3 Exporting to Colombia

The Colombian Institute of Foreign Trade (INCOMEX) classifies imports into two major categories: (1) those requiring a prior import license and (2) those on the Free Import List which do not require a prior import license. Products in both categories are subject to import duties. Approximately 50% of all imports fall under the Free Import List. Eligibility for inclusion on the list is determined by the Foreign Trade Governing Council (Consejo Directivo de Comercio Exterior) of INCOMEX using the following criteria: (a) extent of local production, (b) existence of nationally produced substitutes, and (c) national interest. PV cells are on the Free Import List, but certain systems (i.e. a PV powered refrigerator) would require an import permit because refrigerators are not on the Free Import List.

The U.S. Department of Commerce advises that the following procedures be followed by U.S. exporters whose product appears on the Free List:

1. Submit a completed Import Registration Form (Registro de Importacion) which costs 300 pesos (US$6.00) to INCOMEX

2. Submit the following documents/information along with the import registration form:

   a. Proforma invoice
   b. Importer's income tax payment certificate issued by the Ministry of Finance
   c. A receipt for the 100 pesos (US$2.00) import fee from the Central Bank

In addition, an advance payment of 35% of the import merchandise value must be made to the Central Bank by the importer at least five days prior to the arrival of the merchandise.

There are six free trade zones in Colombia located in the cities of Santa Marta, Barranquilla, Cartagena, Cucuta, Cali (Palmaseca) and Buenaventura. All merchandise entering free trade zones is exempt from the payment of import duties and other surcharges of national, state or municipal origin, as well as from the import license or import registration form requirements.

B.4 Foreign Investment Climate

Colombia's policy towards foreign investment is largely dictated by its membership in LAFTA (Latin American Free Trade Association) and ANCOM (The Andean Common Market). Colombia has been one of the moving forces behind the creation of the Andean Common Market which began with the signing of the Cartagena Agreement in 1969. In 1973, Colombia adopted the Andean Foreign Investment Codes (AFIC) implementing ANCOM Decision 24 which seeks uniformity of foreign investment laws in the ANCOM member countries (Ecuador, Peru, Bolivia, and Venezuela). Chile withdrew from ANCOM in 1976 over a dispute involving foreign investment law.

Implementation of the AFIC is left largely to the discretion of the member countries. Colombia has emphasized the development of extractive and export-oriented industries and has therefore welcomed foreign investment in those areas. The most recent Colombianization of foreign enterprises occurred in 1975 with the nationalization of foreign-owned banks (see Section 4.1). No expropriation of foreign property has occurred without adequate compensation.

The National Planning Department (DNP) reviews all investment proposals except those relating to mining and energy, which are not regulated under the AFIC. Investment proposals in these areas are evaluated by the Ministry of Mines and Energy. Criteria for approval of foreign investment projects by the National Planning Department are:

1. Net effect of the investment on balance of payments
2. Improvements in domestic employment
3. Technological contribution
4. Degree of participation of Colombian capital and management
5. Contribution to economic cooperation in Latin America

Foreign investment is not allowed in public utilities, domestic transport, advertising, television, broadcasting, newspapers and magazines. Acquisition of new stock in existing enterprises is permitted, but it must involve enlargement of the firm's capital base and not alter the percentage of equity capital held by Colombians.

Colombia offers very limited investment incentives. Those incentives that do exist are mainly to promote development in underdeveloped regions and exports. The Plan Vallejo is an export development incentive that permits any product to enter duty free provided the importer can show that the product will benefit Colombian export development. Colombia also offers an income tax credit for non-traditional export industries.

B.5 Forms of Business Enterprise

Business activity in Colombia is governed by the Commercial Code, established in January 1972. Under the code the following types of commercial entities are permitted:

(1) Corporation - Sociedad Anonima
(2) Limited Liability Company - Sociedad de Responsibilidad Limitada
(3) Branch of a Foreign Corporation - Sucursal de Sociedad Extranjera
(4) Various Forms of Partnerships

Joint ventures (cuentas en participación) are not considered juridical entities in Colombia and are commonly used only in connection with petroleum exploration and mining activities. Due to regulations in the Andean Foreign Investment Code regarding sale of shares to national investors, a branch is no longer regarded as a feasible option for foreign firms. Consequently, most foreign firms operate in Colombia as corporations.

For additional information regarding doing business in Colombia, consult:

Business Study Colombia. (New York: Touche Ross International), January 1974.

Doing Business in Colombia. (New York: Price Waterhouse), April 1978

Overseas Business Reports. Marketing in Colombia, (Washington D.C.: U.S. Department of Commerce), May 1979

Overseas Business Reports, Market Profiles for Latin America. (Washington, D.C.:U.S. Department of Commerce), May 1981

APPENDIX C

MAJOR EXPORT AND DOMESTIC CROPS

Coffee

20% of planted land devoted to this crop; 738,000 MT production; $2,289,000,000 export value.

Coffee grows throughout Colombia, but the most productive region is the mountainous Central Highlands. Colombian coffee of export grade ("excelso") is of high quality by world standards and is used to upgrade blends. A member of the International Coffee Organization, Colombia observes export quotas to help control prices. Fourteen percent of production is consumed domestically. The biggest export customers are the U.S. (28%) and West Germany (26.5%). There are over 300,000 coffee farms, a third of which have three acres or less devoted to coffee. The new, highly productive tree varieties require considerable attention and large quantities of fertilizer.

Coffee accounted for 61% of total 1980 export value. An estimated 2 million Colombians work in the coffee industry. Tables 1 to 3 shows characteristics of Colombian coffee production.

Cotton

4% of planted cropland devoted to this crop; 125,000 MT production; $80,000,000 export value

About 11,000 farmers grow cotton, mostly on farms on the Atlantic Coast but also in the interior. Last year overall production was down 14%, due partly to lack of rainfall, especially in the interior, and the resultant 6% drop in yield, and partly to a reduction in planting. The reduction in planting was attributable to a 12% reduction in planting by farmers in the Costa and Meta regions who reacted to credit restrictions and late payments by the textile industry. Over half the production goes to domestic markets. Hungary, West Germany, Poland, and the United Kingdom received legal exports. Illegal imports and exports across the Venezuelan boarder are significant market factors.

TABLE 1 COFFEE BERRY PRODUCTION BY DEPARTMENTS, 1980

DEPARTMENT	SEMESTER A HECTARES PLANTED	SEMESTER A PRODUCTIVITY KG/HA	SEMESTER A PRODUCTION TONS	SEMESTER B HECTARES PLANTED	SEMESTER B PRODUCTIVITY KG/HA	SEMESTER B PRODUCTION TONS
Antioquia	223,330	1,947	434,824	246,309	1,901	468,233
Boyaca	26,142	884	23,110	23,797	949	22,583
Caldas	114,831	1,837	210,945	123,305	2,210	272,504
Cauca	126,043	655	82,558	126,488	604	76,399
Cesar	28,440	897	25,511	28,124	773	21,740
Cundinamarca	87,890	1,081	95,009	97,704	1,090	106,497
Choco	1,102	2,500	2,755	1,082	2,500	2,705
Guajira	5,805	713	4,291	9,087	1,383	12,567
Huila	60,755	1,070	65,008	66,360	1,220	80,959
Magdalena	3,100	1,000	3,100	23,544	968	22,791
Meta	6,541	625	4,083	8,369	664	5,557
Narino	23,501	1,150	27,026	24,160	1,280	30,925
N. Santander	75,987	751	57,066	73,094	728	53,212
Quindio	92,529	1,089	100,764	98,174	1,024	100,530
Risaralda	97,375	1,280	124,512	84,061	1,327	111,548
Santander	52,376	847	44,362	71,753	1,186	85,099
Tolima	170,335	1,161	197,759	196,001	1,199	235,005
Valle	142,571	1,106	157,684	142,077	968	137,531
Casauare	8,115	383	3,108	8,176	300	2,453
Putumayo	48	400	19	25	400	10
Caqueta	2,988	5,000	14,940	2,738	500	1,369

SOURCE: Colombian Ministry of Agriculture
"Estadisticas Agricolas por Cultivo"

TABLE 2

COFFEE HARVEST PERIODS IN DIFFERENT COFFEE PRODUCING DEPARTMENTS

DEPARTMENT	PRINCIPAL HARVEST	MINOR HARVEST
Antioquia	Oct-Dec	Mar-May
Boyaca	Oct-Jan	Apr-May
Caldas	Oct-Dec	Apr-June
Cauca	Apr-June	None
Cundinamarca	Apr-June	Oct-Dec
Cesar, Guajira	Nov-Jan	None
Huila	Apr-June	Oct-Dec
Magdalena	Nov-Jan	None
Narino	May-June	Jan-Feb
N. de Santander	Mar-May	Oct-Dec
Quindio	Mar-May	Oct-Dec
Risaralda	Oct-Dec	Apr-June
Santander	Aug-Oct	None
Tolima	Mar-June	Nov-Jan
Valle	Mar-May	Nov-Jan

SOURCE: Manual del Cafetero Colombiano

TABLE 3

PERCENTAGE OF COFFEE HARVEST BY MONTH IN CALDAS AREA IN COLOMBIA

MONTH	PERCENTAGE
Jan	5.4
Feb	2.7
Mar	3.0
Apr	3.0
May	1.8
June	1.6
July	2.6
Aug	6.4
Sept	13.9
Oct	25.2
Nov	23.0
Dec	11.4
Major Harvest	80%
Minor	20%
Peak Day	2%

SOURCE: Manual del Cafetero Colombiano

Sugar

2.5% of planted land devoted to this crop; 1,992,000 MT production; $500,000,000 in export value.

White sugar is harvested year-round in large, highly efficient, mechanized and fully irrigated estates in the Cauca Valley and along the Atlantic coast. Export prices are sometimes so much higher than the controlled domestic prices that smuggling becomes rampant. Of legal exports, the U.S. and Chile receive about 45% each. Colombia recently joined the International Sugar Agreement and thus has export quotas for sugar. In 1975 Colombia had twenty-one sugar mills.

Panela (brown sugar)

5.1% of planted land devoted to this crop; 800,000 MT production; 1600 MT exported.

Brown sugar is produced by small landowners in rural areas throughout the temperate and hot zones. 64% is produced in coffee growing areas. Rural inhabitants are the major domestic consumers, and 90% of exports go to Venezuela.

Molasses

341,000 MT production; 144,000 MT exported.

Molasses production is tied to sugar production, as molasses is produced in the sugar refining process. The liquor industry accounts for 60% of domestic consumption but is turning more to brown sugar and sugar cane juice. All exports go to the U.S.

Rice

8% of planted cropland devoted to this crop; 1,892,000 MT production (1,230,000 MT milled); 100,000 MT milled rice exported.

An important staple, rice is consumed for the most part in Colombia. Only about 8% of milled rice production was exported. The rice went to the French Antilles, Poland, Italy, Ecuador, United Kingdom, Nicaragua, and Honduras. The feed industry and bakers use milling by-products, and breweries use low quality rice. Rice production is 77% mechanized. Tolima Department, in a Central Highlands Valley, produces about a third of Colombia's rice. Lack of rain during the growing season and reduced irrigation levels resulted in a lower yield in 1980.

Plantains

8% of planted cropland devoted to this crop; 2,348,000 MT production; 36,000 MT exported.

Plantains are widely grown and consumed.locally Colombia has the world's highest per capita consumption. Plantains are exported to the U.S. from the Gulf of Uraba area in the Atlantic Lowlands.

Cassava

4% of planted cropland devoted to this crop; 2,639,000 MT production; 7,000 MT exported.

Like rice and plantains, cassava is grown as a domestic staple rather than as an important export. The short shelf-life of cassava makes domestic consumption logical. Often grown in rotation with other staples, cassava is beginning to be industrialized. In 1980, production and yield increased by about 25%, and further improvements in yield are anticipated.

Bananas

0.5% of planted cropland devoted to this crop; 1,081,000 tons production; $98,000,000 export value.

Two-thirds of the banana crop is exported. The biggest purchaser is the United States (1/3 of exports), followed by France, West Germany, and Italy. 80% of export bananas are grown in the Uraba area in the Atlantic Lowlands, and the remainder are grown in North Central Colombia (Santa Marta region). Both production and yield of bananas increased in 1980, and further increases are expected. Banana production is fully mechanized.

Corn

11% of planted cropland devoted to this crop; 831,000 MT production; no exports.

In 1980, only 85% of Colombia demand for corn was satisfied with domestic production due to drought. Imports, normally from the U.S., are expected to be halved in 1981. Corn production is 20% mechanized and

irrigated, and some farmers use high yield varieties. Overall, however, yield is just over 20 bushels per acre, compared to over 120 bushels per acre with modern methods, irrigation and high yield strains. Corn production is centered in the Northern Coast region, the Central Highlands valleys, and the Meta region.

Flowers

0.2% of planted cropland devoted to this product; 78.6 million dozen production; $90,000,000 export value.

Unusually intensive cultivation characterizes the flower industry. Requiring 1/24 the land of a similarly valued banana crop, flower culture is highly mechanized, and 60% of the product price corresponds to labor. Since 1973 the industry has rapidly grown to employ 400,000 people and has become a major exporting industry. 70% of exports go to the United States. Major varieties are carnations (62%), pompoms (21%), chrysanthemums(8%), and roses (4%). About 90% of the industry is located in the Bogotá area.

Tobacco

0.5% of planted cropland devoted to this crop; 1,580,000 MT production, 18,000 MT exported.

87% of tobacco production is the dark leaf (cigar binder) type. Coastal areas produced 16,300 MT for export and interior areas produced 19,450 MT for domestic consumption. Light leaf (cigarette type) tobacco production totalled 5,400 MT of which 600 were exported. Light leaf tobacco is increasingly important both for exports and for domestic use. Perhaps 90% of total tobacco production is on very small farms. The industry is largely not mechanized.

Potatoes

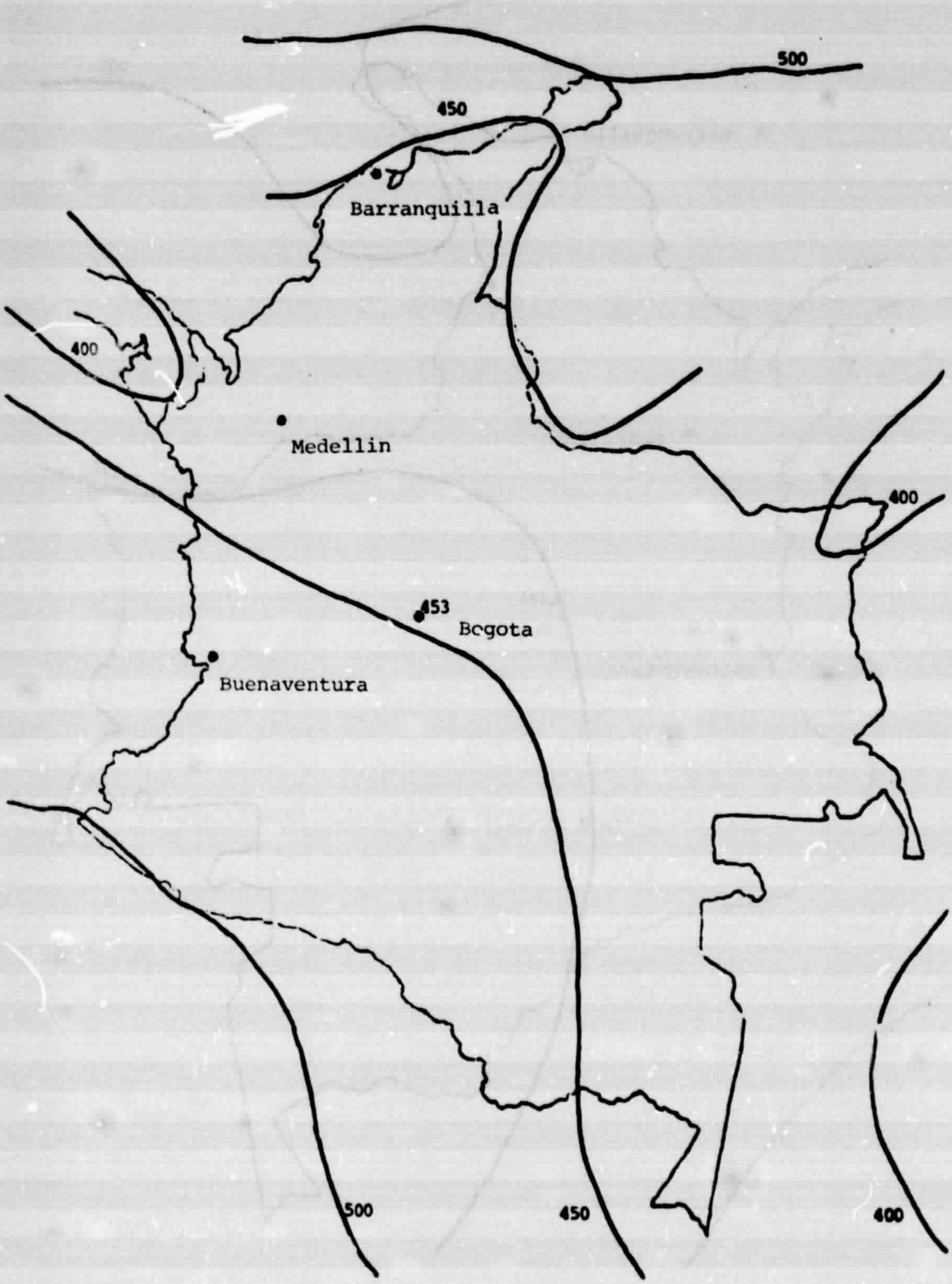
3% of planted cropland devoted to this crop; 2,134,000 MT production; 2,000 MT exported.

Drought during planting seasons was responsible for a 5% decrease in potato crop yield in 1980. No irrigation is used in the

industry; however, fertilization is common. Production takes place largely on small, unmechanized farms in the highlands. Potatoes are an increasingly important staple for low-income Colombians. For this reason, the government has not encouraged exports.

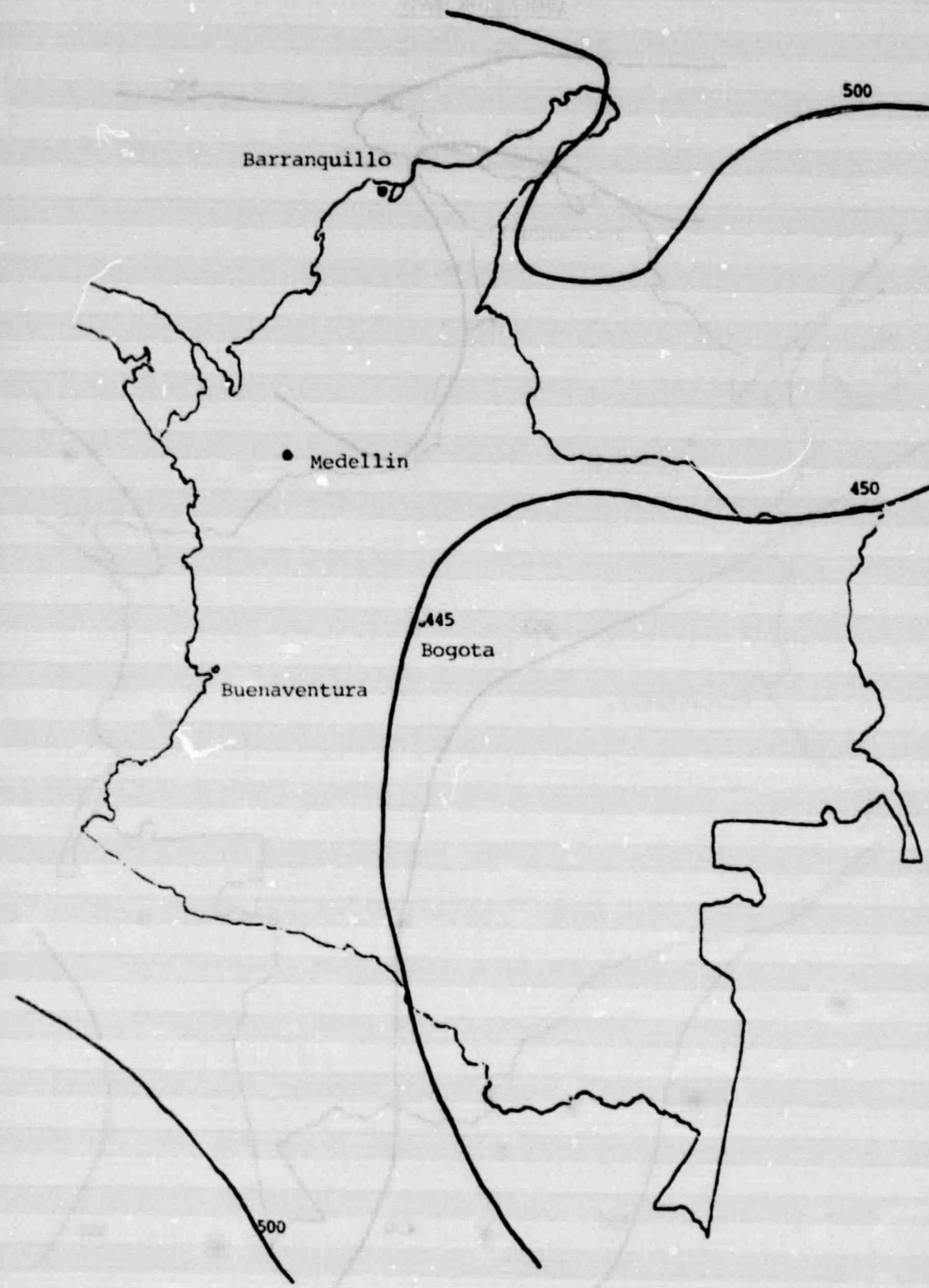
APPENDIX D

ISOLATION DATA



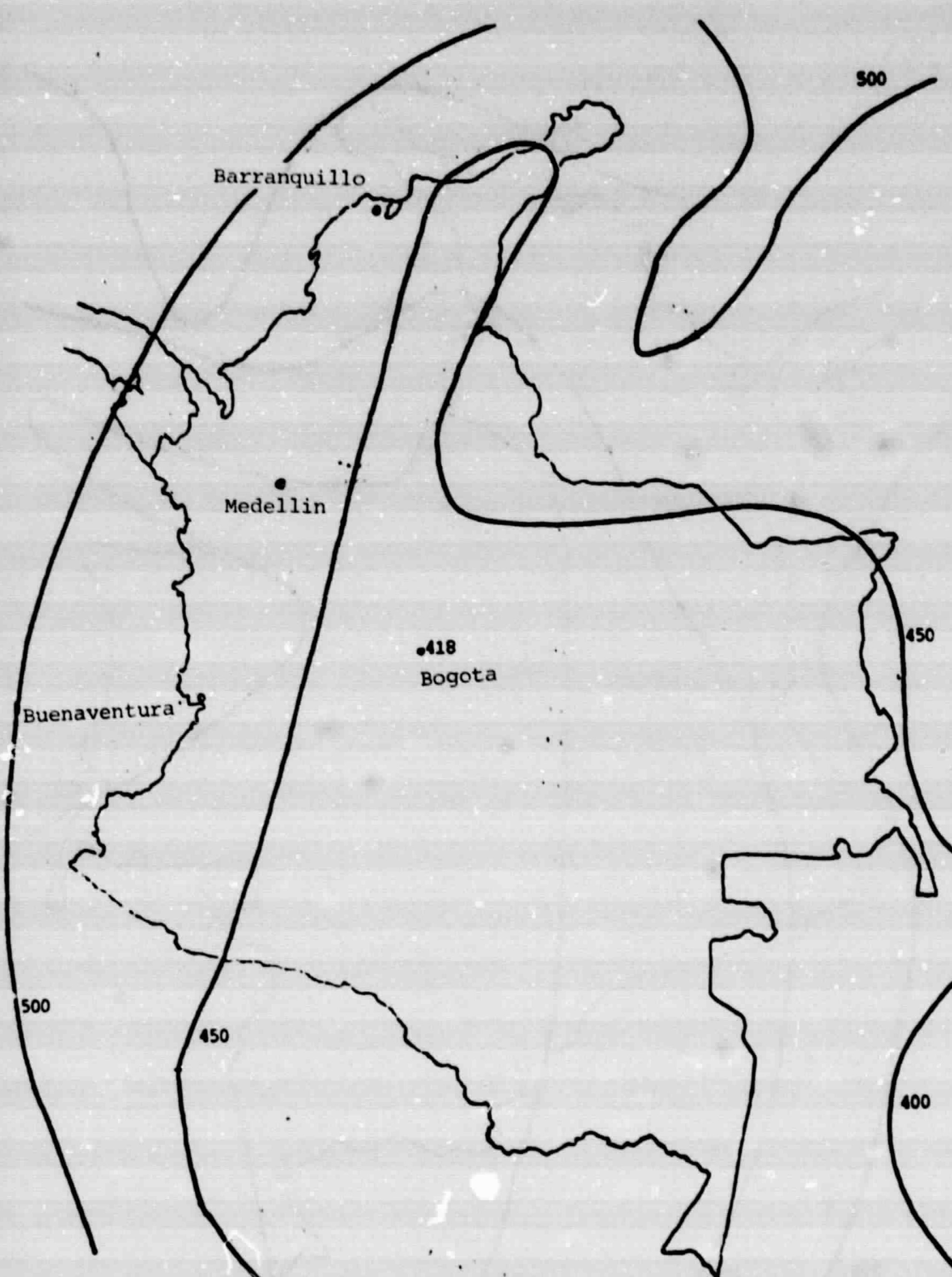
January Mean Daily Solar Radiation (GM Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energía Solar



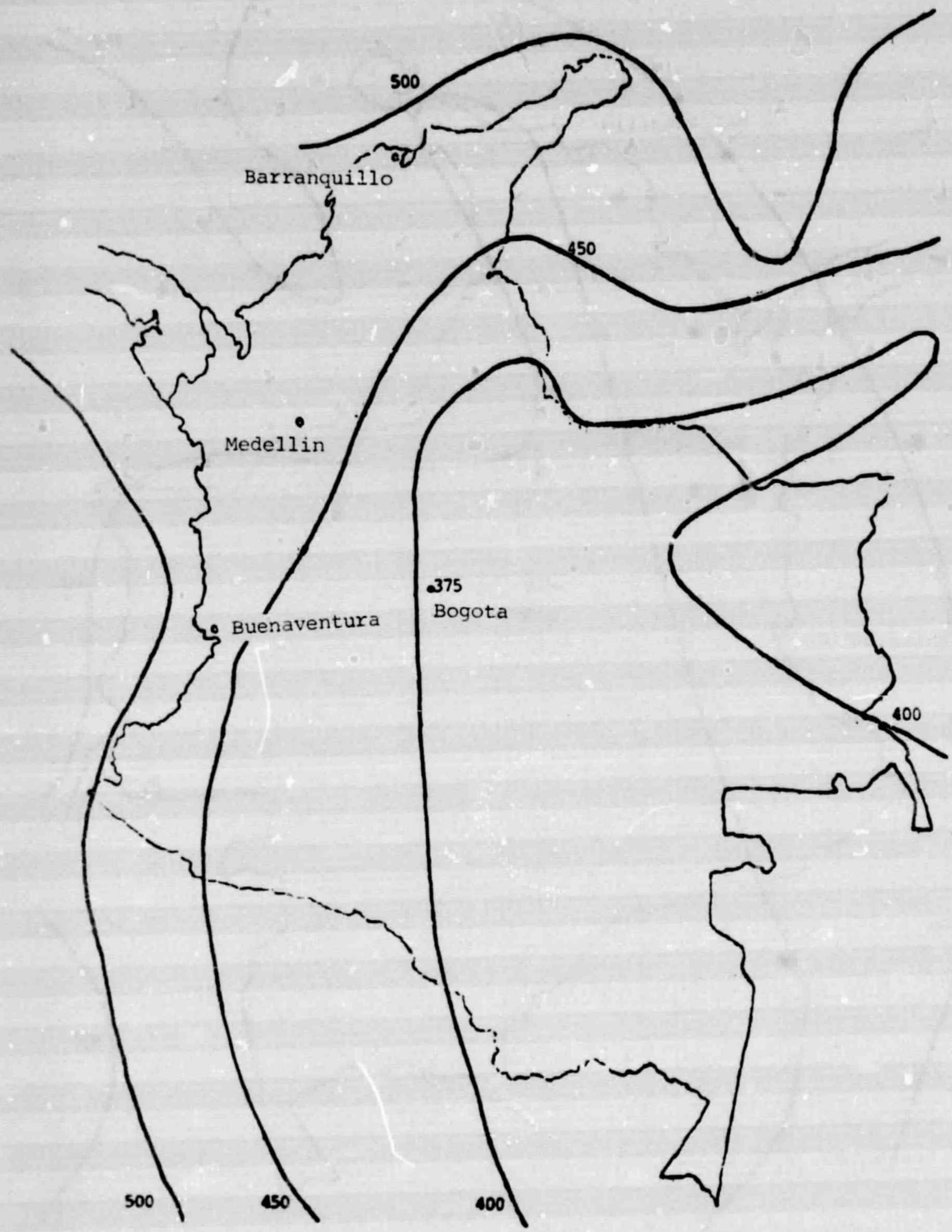
February Mean Daily Solar Radiation (GM Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar

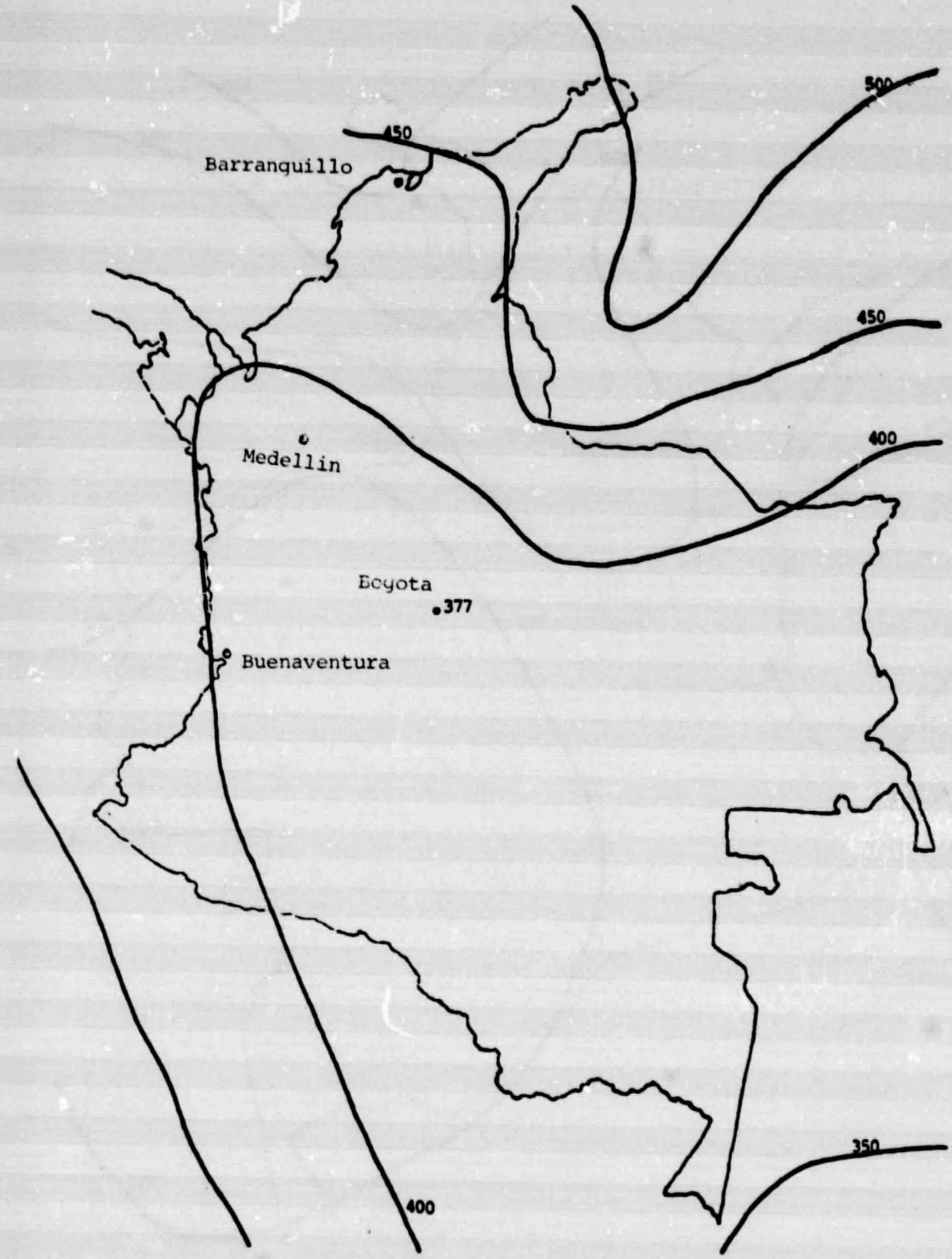


March Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar

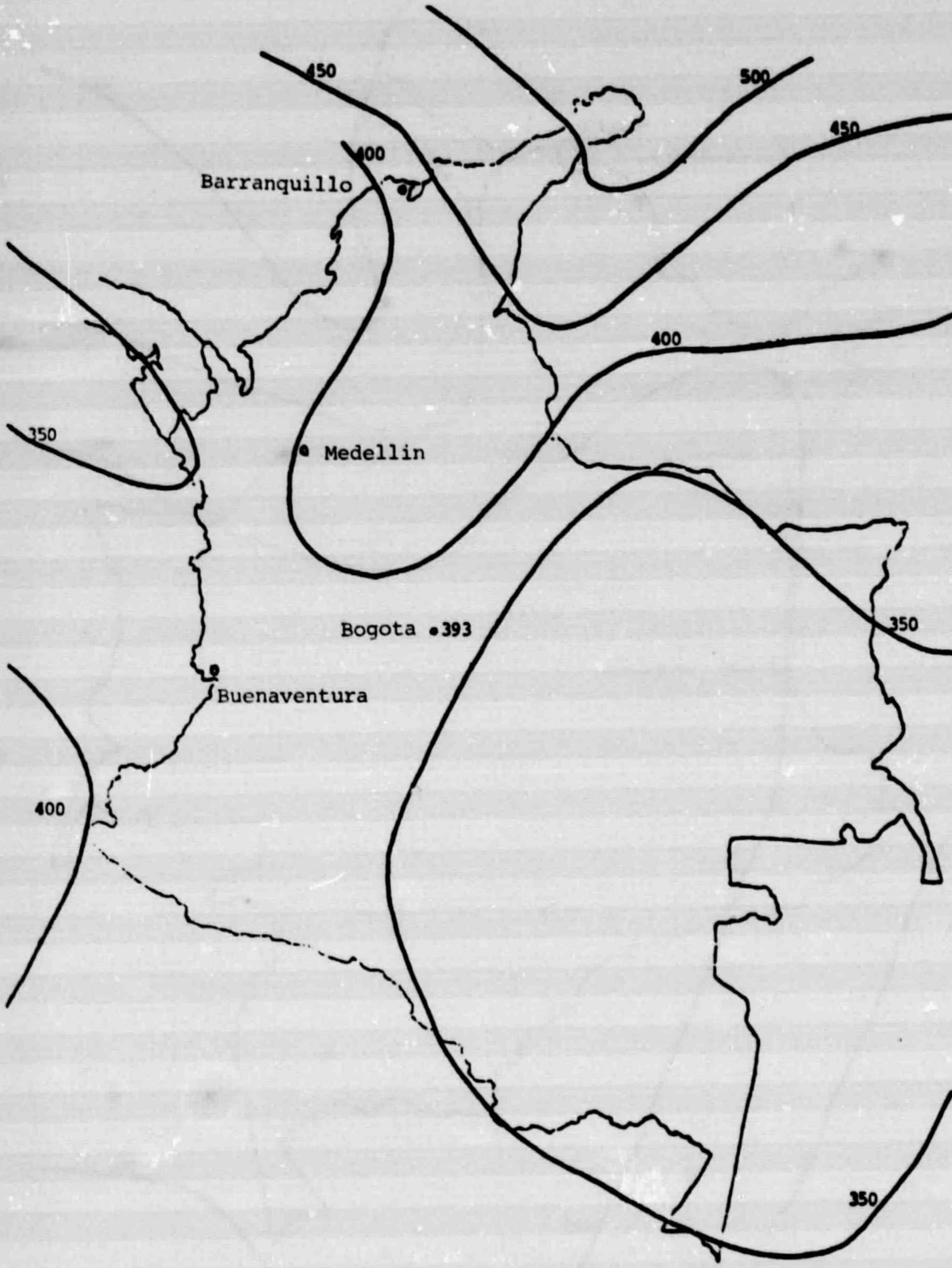


April Mean Daily Solar Radiation (Gm Cal/cm^2/day)
SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar



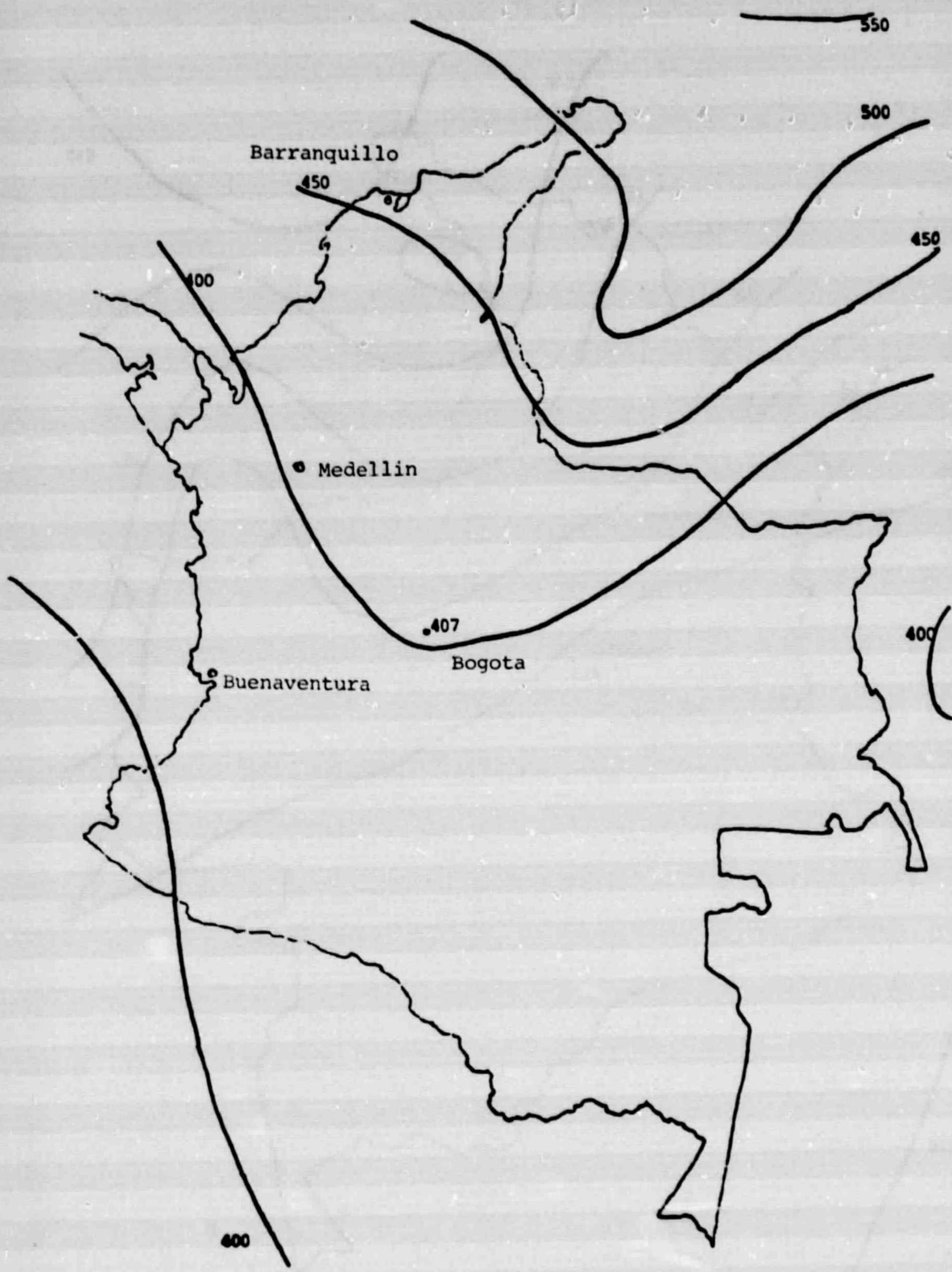
May Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar



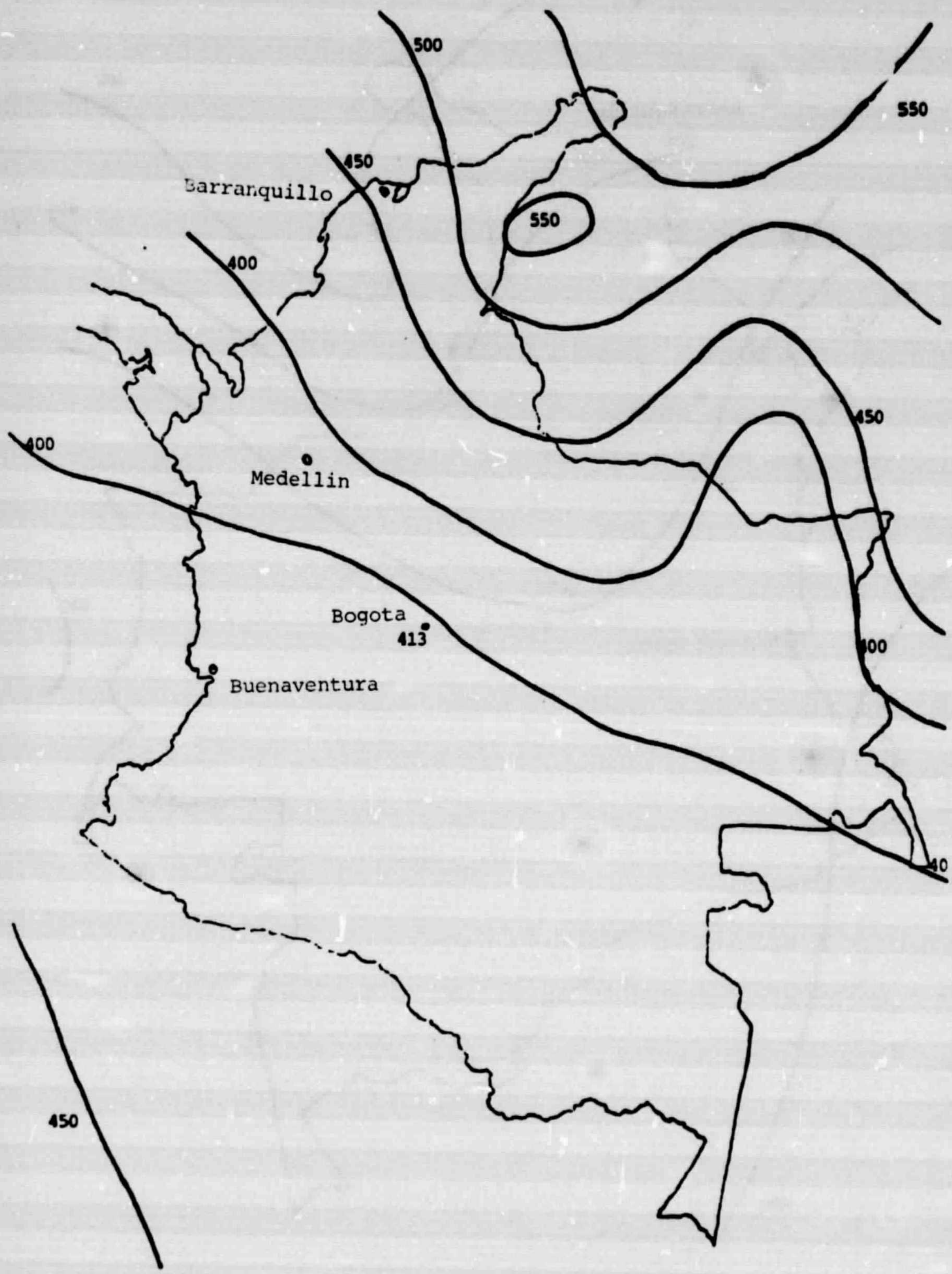
June Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar



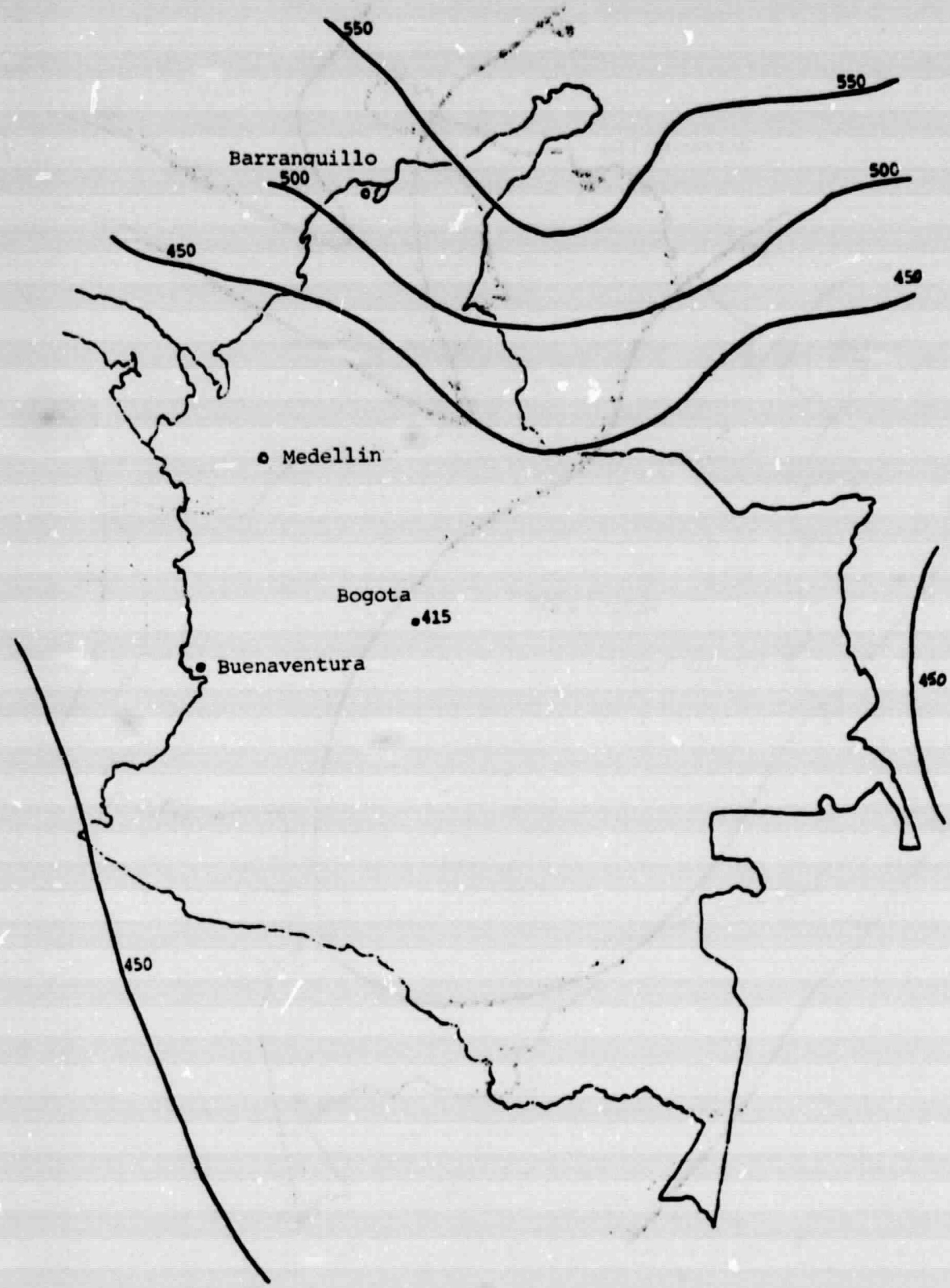
July Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar



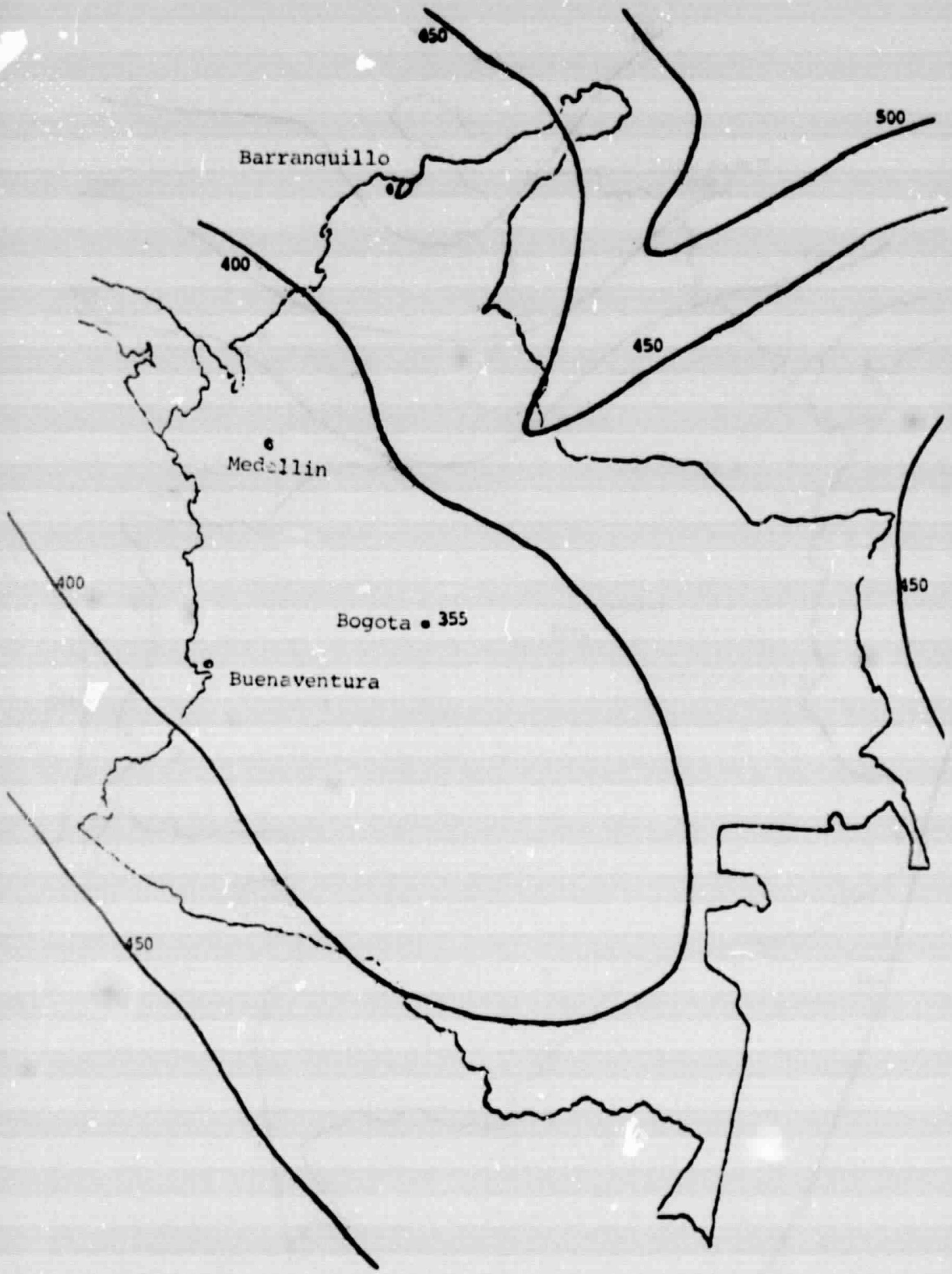
August Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar

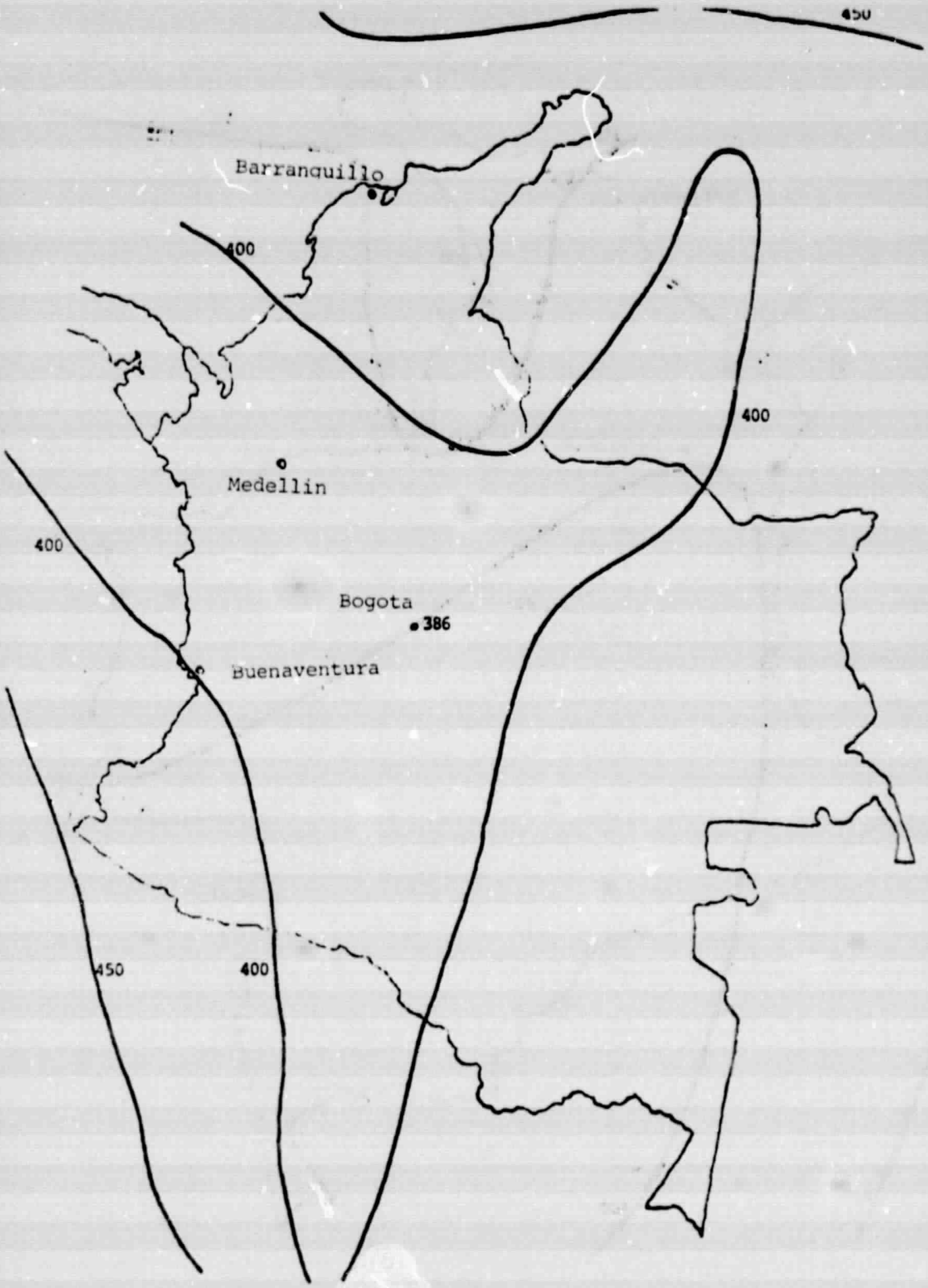


September Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar



October Mean Daily Solar Radiation (Gm Cal/cm^2/day)
SOURCE: Instituto de Asuntos Nucleares, Pro[illegible]ecto Energia Solar



November Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar

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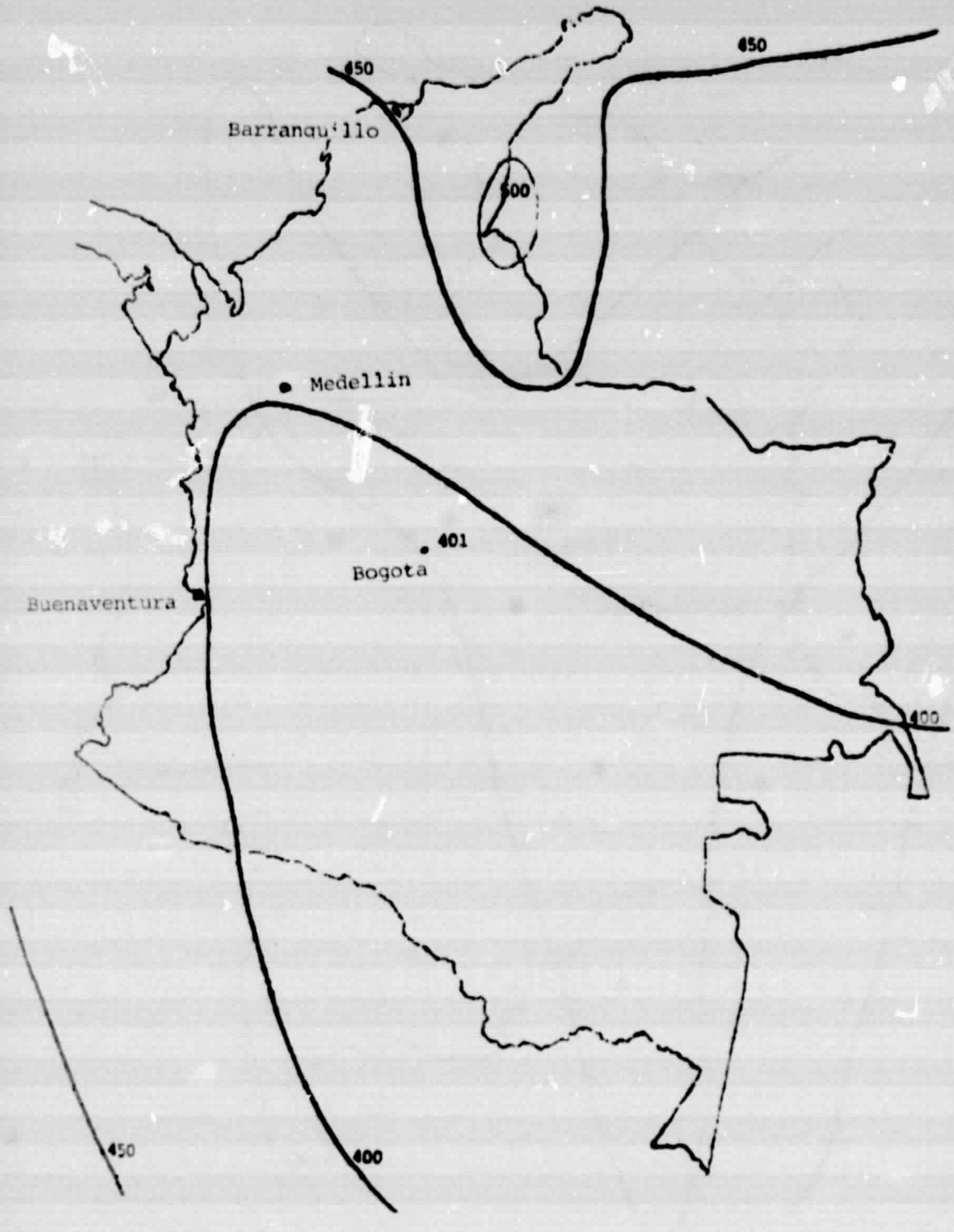

December Mean Daily Solar Radiation (Gm Cal/cm^2/day)

SOURCE: Instituto de Asuntos Nucleares, Proyecto Energia Solar

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APPENDIX E

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